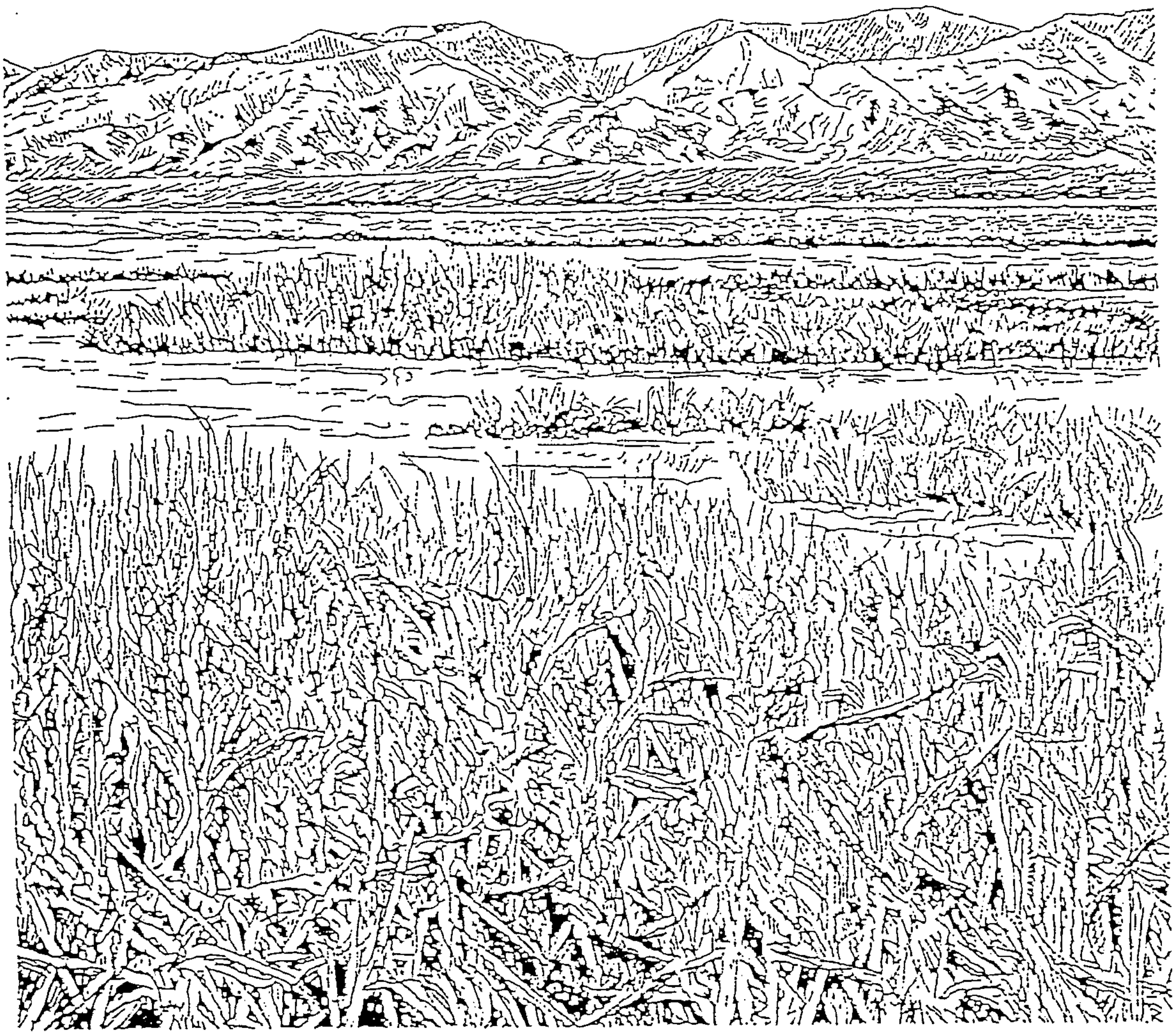
APRIL 1993

WETLAND MODELING AND INFORMATION NEEDS AT STILLWATER NATIONAL WILDLIFE REFUGE



Fish and Wildlife Service

U.S. Department of the Interior

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FISH AND WILDLIFE SERVICE
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TAKE PRIDE IN AMERICA

In Reply Refer To:
FWS/Region 8/NERC

April 16, 1993

HMP 402.906

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Memorandum

To: Ron Anglin, USFWS

From: Dave Hamilton, Habitat Management Project

Subject: Stillwater NWR Workshop Report

Enclosed is your copy of the Stillwater National Wildlife Refuge workshop report. We have incorporated most of the review comments into this final version and hope that it now adequately reflects discussions during the workshop. Also enclosed is a copy of The Nature Conservancy's Lahontan Valley literature review.

We would like to thank you again for your participation in this project. Your ideas will be extremely useful as the refuge addresses water management issues and potential expansion of refuge boundaries in the future.

Attachment

April 1993

WETLAND MODELING AND INFORMATION NEEDS AT STILLWATER NATIONAL WILDLIFE REFUGE

by

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Gregor T. Auble

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Results of a workshop sponsored by
Division of Refuges and Wildlife, Region 1
U.S. Fish and Wildlife Service

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INTRODUCTION

Workshop Objectives and Approach

The marshes in and around Stillwater National Wildlife Refuge (the Refuge) are extremely dynamic; expanding and contracting in size both seasonally, due to runoff and subsequent evapotranspiration, and over longer periods, due to climatic variation. The dynamic nature of these marshes results in a diversity of wetland habitats, which support a variety of migratory birds. To maintain this wetland diversity and control the loss of migratory bird habitat in the Lahontan Valley, the Refuge was established and currently manages a complex of marsh units. However, changes in the hydrology, and changes that will occur as a result of the Fallon Paiute-Shoshone and Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Public Law 101-618, 104 Stat. 3389), greatly affect the Refuge's wetland management capability. In light of these changes, and the legal requirements associated with environmental impact assessments, the Refuge convened a workshop to discuss several aspects of wetland management in the Lahontan Valley. The workshop, described in this report, had three primary objectives:

1. discuss the types and relative proportions of primary wetland habitats that should be provided as described in the settlement act;
2. discuss wetland management models that might be developed to help manage these marshes under hydrologic regimes likely in the future; and
3. discuss future information and monitoring needs, including proposals for valley-wide biodiversity surveys, which would be helpful when considering withdrawn Bureau of Reclamation (BR) lands for possible incorporation into the Refuge.

Several presentations at the beginning of the workshop provided a common basis for discussing these objectives. Refuge staff provided background on the history and past management. The Nature Conservancy discussed their role in the settlement act, proposals for valley-wide biodiversity surveys, and results of a literature review for Stillwater Marsh and the Lahontan Valley (Nachlinger 1993). Kay Fowler provided an historical context of changes in vegetation and waterbird use of the marshes based on her ethnography of the local Paiute Indians (Fowler 1993). Finally, Bob Elston discussed a model that predicts archaeological sites based on environmental variables (Raven and Elston 1989).

The workshop was organized by staff from the Refuge and facilitated by the authors of this report. Participants included Ron Anglin, Bill Henry, Anne Janik, Cliff Creger, Fred Paveglio, and Mary Jo Elpers of the U.S. Fish and Wildlife Service (the Service); Jeff Baumgartner, Jan Nachlinger, Hope Humphries, and Graham Chisholm of The Nature Conservancy; David Yardas of the Environmental Defense Fund; David Robertson of Robertson Software, Inc.; Norm Saake, Terry Retterer, and Larry Neel of the Nevada Department of Wildlife; Lew Oring and Kay Fowler of the University of Nevada; and Robert Elston of Intermountain Research.

Background

The marshes in the Lahontan Valley of Nevada are terminal wetlands at the end of the Carson River (Figure 1). Much of the following background information on these wetlands has been summarized from Anglin and Shellhorn (1992). The marshes expand in size in the spring because of runoff from the adjacent mountains and contract through the summer due to evaporation and transpiration, often leaving alkaline flats. They also expand and contract as a result of longer-term climatic conditions. For example, the marshes extended over approximately 215,000 acres during the 1984-85 flood but are almost completely dry currently due to drought conditions since then. It is this dynamic nature of the water regime, both within and among years, that maintains these marshes. When they are wet, these marshes are among the most productive wetlands in the world. This productivity and the diversity of wetland habitats support a variety of migratory birds, including ducks, geese, pelicans, marsh birds, and shorebirds, as well as indigenous mammals, reptiles, and amphibians. As the marshes dry out, concentrations of salts and trace elements may increase to toxic levels, killing fish and other species unable to migrate. When the wetlands are dry, sediments are consolidated and aerated, salts encrusted on the surface are blown away, and plant succession is set back.

Terminal wetlands of the Great Basin in general, and marsh units at the Refuge in particular, are composed of a series of ponds or management units whose progressive expansion and contraction explains the diversity of wetland habitats. For explanatory purposes, consider the four ponds shown in Figure 2. In early spring, fresh water (i.e., 200-400 μmhos/cm) from snow melt initially fills pond A. As the runoff continues, the down-gradient ponds B, C, and D are progressively filled. As water enters each pond, it dilutes (freshens) any residual water from the previous year. However, mixing

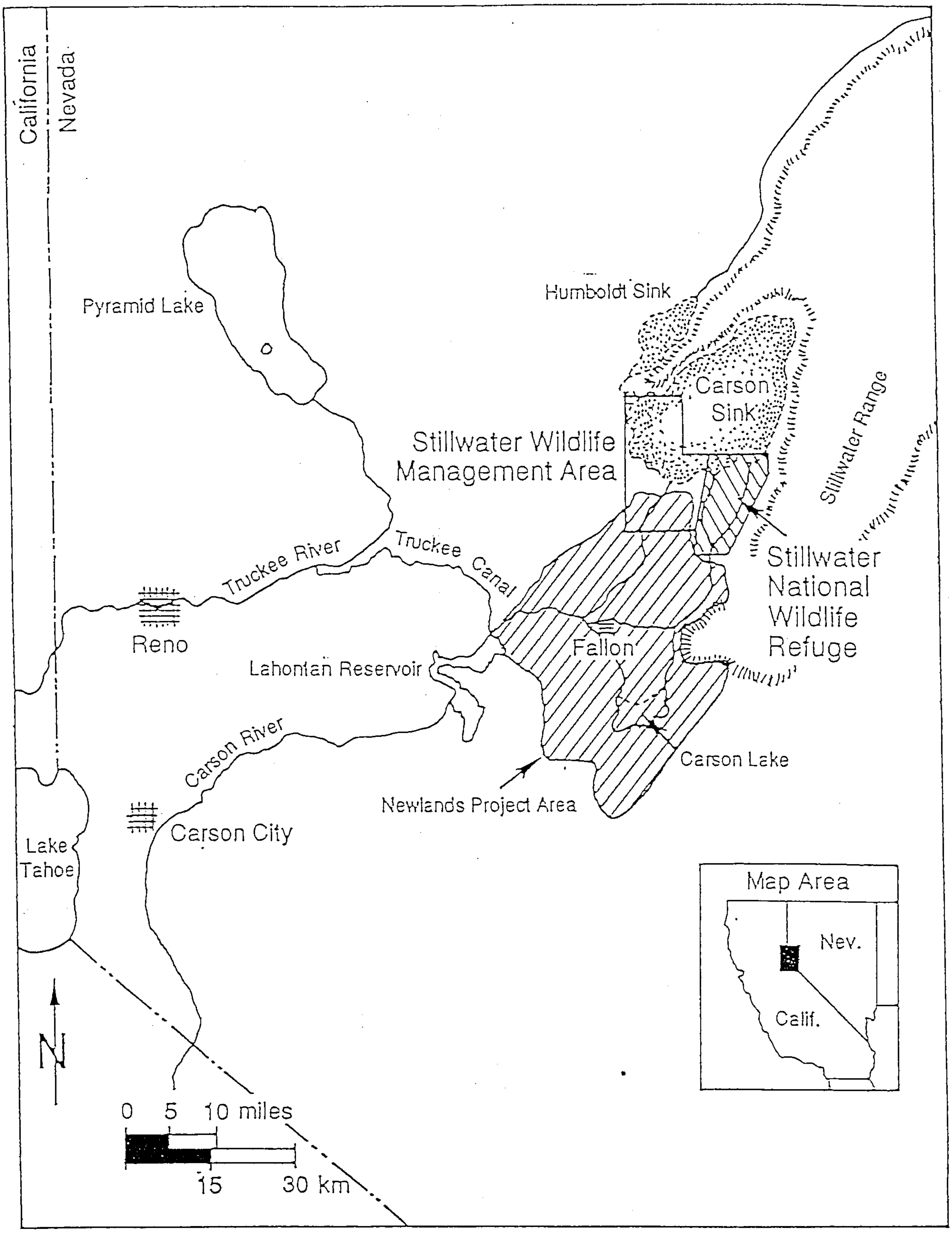

Figure 1. Stillwater National Wildlife Refuge and vicinity.

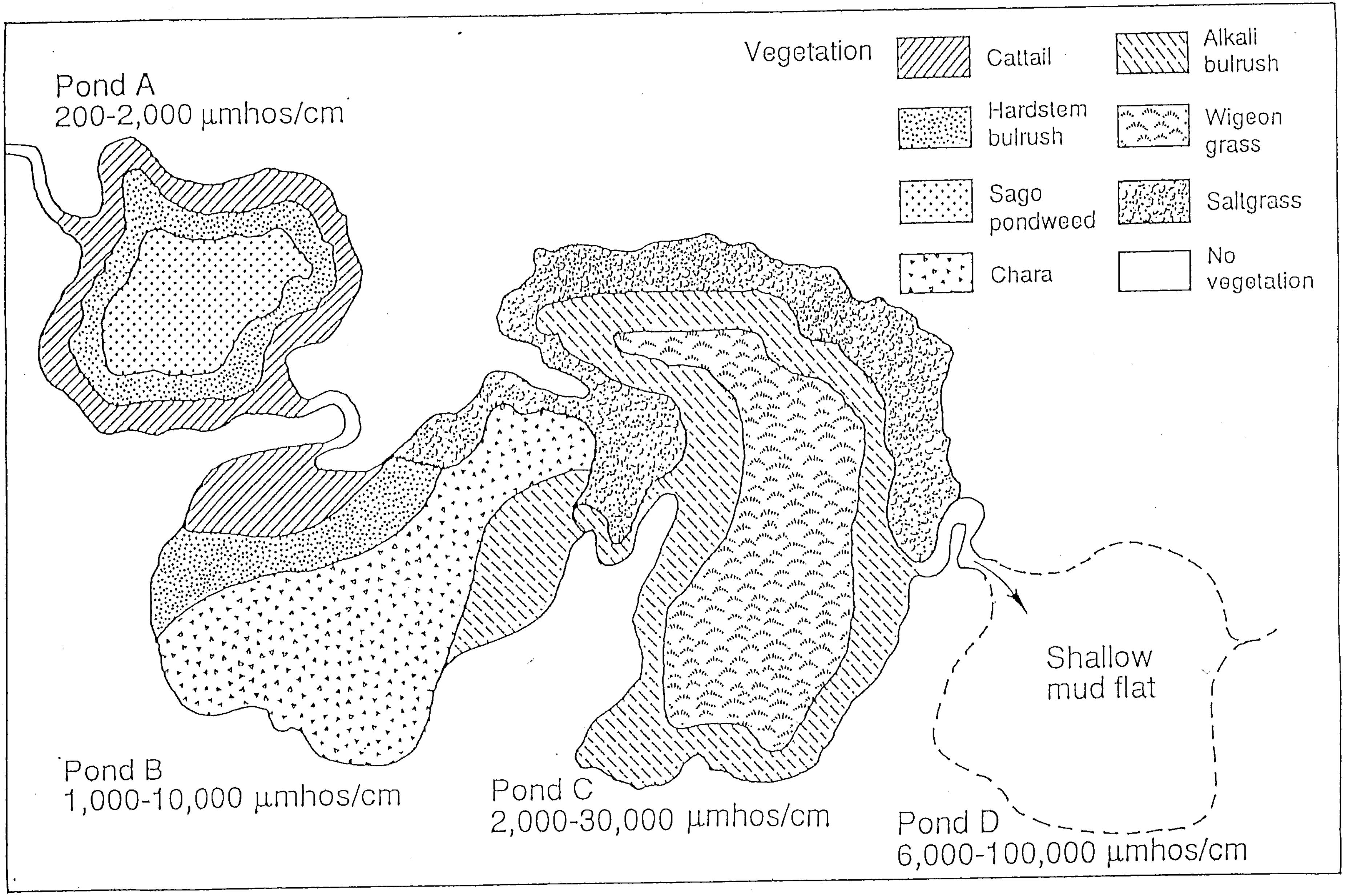

Figure 2. Hydrologic regimes of Great Basin wetlands.

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with residual water and contact with salt encrusted alkaline soils of dry ponds means that water quality is degraded and runoff to the next pond is more saline. By the end of spring runoff, water in the lower ponds may have a specific conductance of 6,000 - 10,000 µmhos/cm. During the summer, evaporation concentrates the salts and the ponds begin to contract. Pond D will dry out first with specific conductance reaching levels of 100,000 µmhos/cm before becoming a salt-encrusted playa. As a result of the drying and high salinities, little, if any, vegetation is found in these lower ponds. However, these ponds are extremely productive in terms of invertebrate populations during the summer when they have water. Pond C will dry out next, but may maintain moist soil conditions into the winter. Specific conductance may be as high as 30,000 µmhos/cm. Salt-tolerant plants such as saltgrass, alkali bulrush, and widgeongrass will be found in this pond. Pond B will often still have shallow water at the end of the summer with specific conductance ranging from 1,000 - 10,000 µmhos/cm. Salt-tolerant species such as alkali bulrush and chara may be found nearer the outflow and less salt-tolerant species such as cattail and hardstem bulrush near the inflow. Except in years of extreme drought, Pond A will be maintained as a permanent marsh with reasonably good water quality. Typical vegetation includes cattail, hardstem bulrush, and sago pondweed. Thus, ponds in the marsh progress from relatively permanent with fresh water at the upper end to more ephemeral and saline at the lower end. Historically, spring flows entered the marsh through the Stillwater Slough and flowed clockwise through the various marsh units (Figure 3). Thus, the units associated with the Canvasback Gun Club were typically the most permanent and freshest, while Goose Lake was the most ephemeral and saline (units south of Division Road were not created until after the Refuge was established).

The natural hydrologic regime of marshes in the valley was altered in 1915 when Lahontan Reservoir was constructed. Waters below the dam were routed through a network of channels instead of flowing through natural channels. For example, much of the water now entered through the Diagonal Drain and flowed counterclockwise through the marshes. While drain water from irrigated lands in the Newlands Project still reached the marshes, flows were more constant over a longer period in the summer, corresponding to the irrigation season, rather than arriving as a large volume of flow in the spring. In addition, approximately half of the Truckee River flow, on average, was diverted to Lahontan Reservoir for irrigation use in the summer and power generation in the winter. These changes altered the composition and cover of the marsh vegetation. For example, Dave Marshall, the first refuge biologist, estimated that between 1900 and 1952, the

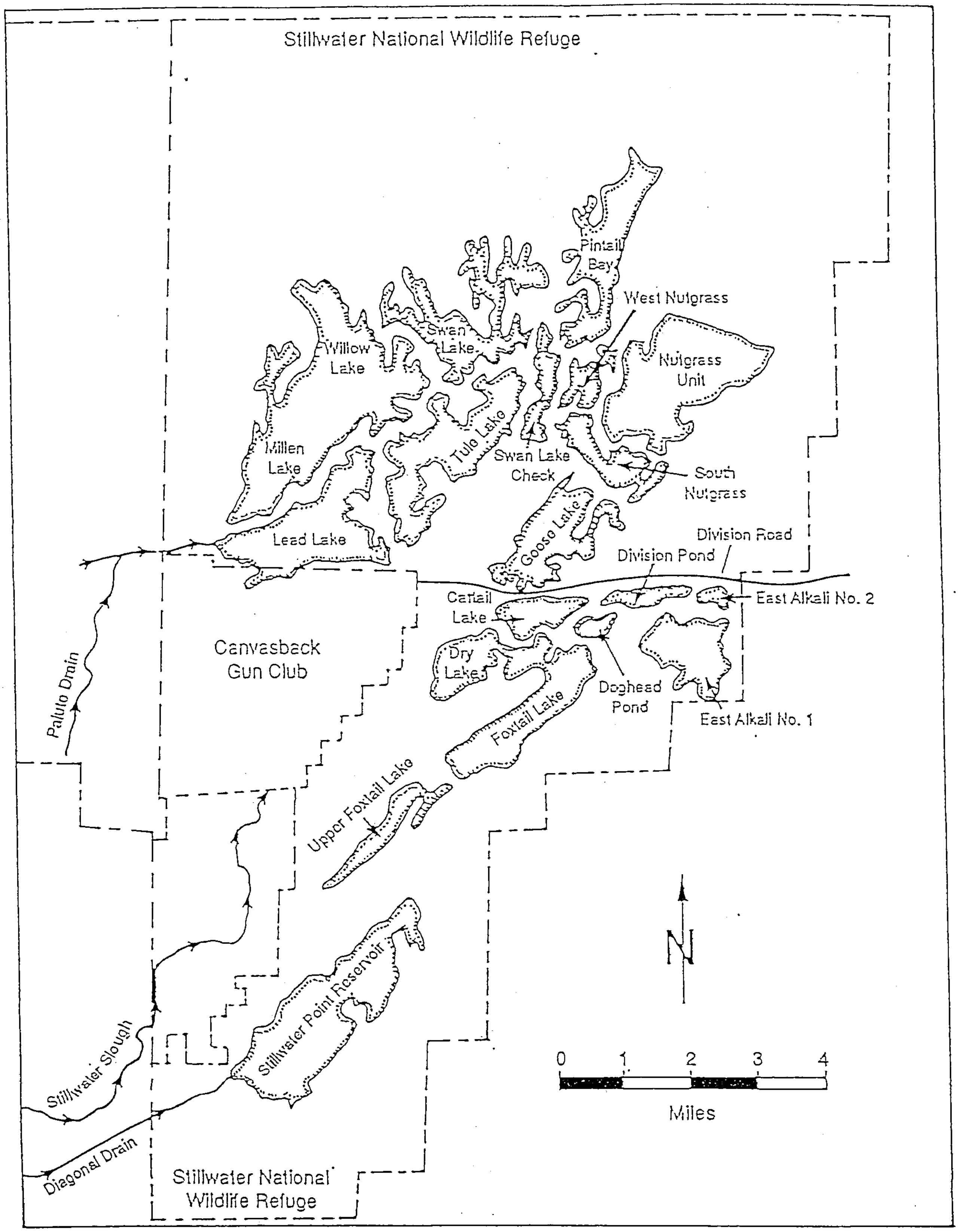

Figure 3. Marshes at the Stillwater National Wildlife Refuge.

acreage of hardstem bulrush was cut in half while the acreage of cattails almost tripled (U.S. Fish and Wildlife Service 1952).

In 1948, in an effort to control the loss of migratory bird habitat in the Lahontan Valley, the U.S. Fish and Wildlife Service, the Nevada Fish and Game Commission, and the Truckee-Carson Irrigation District entered into an agreement to manage the marshes. In order to best use available water resources, approximately 30 miles of dikes and 70 miles of canals and ditches were constructed, and over 200 water control structures were installed. Most of the wetland management units south of Division Road were created as a result of this development. With these facilities, the Service was able to manage drain flows and maintain a diversity of wetlands.

The hydrologic regime of marshes in the valley was further modified in the late 1960s when a Department of Interior Task Force recommended stopping all diversions from the Truckee River for winter power generation and limiting the maximum allocation of irrigation water for the Newlands Project to 406,000 ac-ft. Without winter power generation, large volumes of good quality water were no longer available to flush salts from the marsh or support the warm water fishery and muskrat trapping created as a result of managing waterfowl nesting habitat. The reduced volume of irrigation drainwater was no longer adequate to maintain the marshes as they had been developed in the late 1940's, and the wetland habitat subsequently decreased.

The Fallon Paiute-Shoshone and Truckee-Carson-Pyramid Lake Water Rights Settlement Act, passed in 1990, contains a number of provisions related to wetland resources in the Lahontan Valley (Yardas 1992). The act directs the Secretary of Interior to sustain approximately 25,000 acres of primary wetlands in the Lahontan Valley in order to conserve fish and wildlife resources and maintain and restore biological diversity. The primary wetlands include approximately 14,000 acres of marsh at the Refuge, 10,200 acres at Carson Lake, and 800 acres in the Fallon Indian Reservation. The Secretary was authorized to acquire Newlands Project irrigation rights to meet this objective. An Environmental Impact Statement (EIS) concerning the water rights acquisition is due in 1993. The acquisition authorities were modeled after an existing program involving the Nature Conservancy and the U.S. Fish and Wildlife Service. In this program, the Nature Conservancy acquired marginal farmland within the Newlands Project, took it out of production, and transferred the associated water rights to the Refuge. In some cases, taking marginal farmlands out of production may have an added benefit in that the associated waters no longer contain the elevated levels of arsenic, boron, and other heavy metals typically leached out of the soils through irrigation. However, differences in the relative contributions of various marginal farmlands to water quality problems in the Lahontan Valley are not currently well understood. The act also provides for the expansion of the Refuge, including possible incorporation of withdrawn BR lands. An EIS on this expansion must be completed by 1997.

The next three sections of this report summarize the discussions associated with each of the workshop objectives; types and proportions of primary wetland habitats, wetland management models that might be developed, and future information and monitoring needs. The final section of the report summarizes workshop conclusions and recommendations.

REFUGE OBJECTIVES AND WETLAND COMMUNITIES

Refuge Objectives

(old objectives) pre-1990

Current Refuge objectives address the following six basic elements:

- Production of redheads; white-faced ibis; shore and water birds; and waterfowl.

- Maintenance of redheads and canvasbacks; tundra swans; waterfowl; white-faced ibis; white pelicans; and shore, marsh, and water birds.

- Maintenance of bald eagles and peregrine falcons.

- Wildlife diversity.

- Public use.

- Cultural resources.

At some refuges, numeric objectives for fish and wildlife use-days or production provide clear criteria for both planning and operational management decisions. There was some discussion at the workshop concerning how rigidly to interpret current Refuge objectives. In particular, it was suggested that current Refuge objectives reflect an earlier hydrologic regime in which the Refuge was receiving more water and was receiving water in an unnaturally uniform temporal pattern because of power generation, large irrigation return flows, and spills from the irrigation delivery system. Thus, current Refuge objectives may weight species dependent on deep and semi-permanent marsh habitats more than would be appropriate with either a natural (pre-development) hydrologic regime or with the current hydrologic regime. On the other hand, the ability to call for deliveries of acquired water rights at specific times, as well as the internal water delivery system and multiple marsh units, provide flexibility in the types of habitat that could be provided.

There was also discussion at the workshop concerning how current or future Refuge objectives related to the potentially broader biodiversity goals in the settlement act. One position was that biodiversity goals could be expressed and tracked through target vertebrate species. Another position was that large scale surveys of the Lahontan Valley were needed as a reference to formulate specific biodiversity objectives for the entire 25,000 acres of primary wetlands (i.e., to determine which wetland habitats and communities most need protection or enhancement). We did not resolve these issues at the workshop, either in terms of reformulating existing Refuge objectives or by identifying the areas of specific types of habitat that should be represented in the 25,000 acres of primary wetlands. Rather, we used current Refuge objectives as a general indication of the species the Refuge was trying to support and thus of the types of habitat that would be required in at least a substantial part of the 25,000 acres of primary wetlands.

Habitat Types and Conditions

Marsh management at the Refuge consists largely of providing particular combinations of vegetation and water levels that constitute habitat for various species groups. Anglin and Shellhorn (1992) summarized the general marsh habitat types of Great Basin wetlands in terms of water depth and vegetation and identified representative species associated with these habitats. The basic habitat types considered at the workshop included: uplands, mud/alkali flats, saltgrass meadow, emergent marsh (shallow and deep), and submergent marsh. Figure 4 illustrates the water depths, characteristic vegetation, and wildlife food resources associated with these habitat types. Discussion at the workshop modified the species distributions slightly from Anglin and Shellhorn's original diagram. Figure 5 shows the habitats used by various bird species for nesting, and thus those habitats contributing to avian production objectives. Figure 6 summarizes feeding habitat preferences (maintenance objectives) for a number of species. Eagle habitat consists of perch trees and food. Food in the form of young birds or fish would be provided across all the habitat types.

Hydrology and water quality are the dominant factors determining marsh vegetation. However, the relationship between hydrology and vegetation in these systems is complex and variable. In workshop discussions of water quality as it affected plant distributions, we used salinity, total dissolved solids (TDS), and conductivity interchangeably, though we recognized that the relationships between these variables were not precise. Plant species have different optima and ranges of tolerance to both water depth and salinity. We developed several tables at the workshop to identify how much

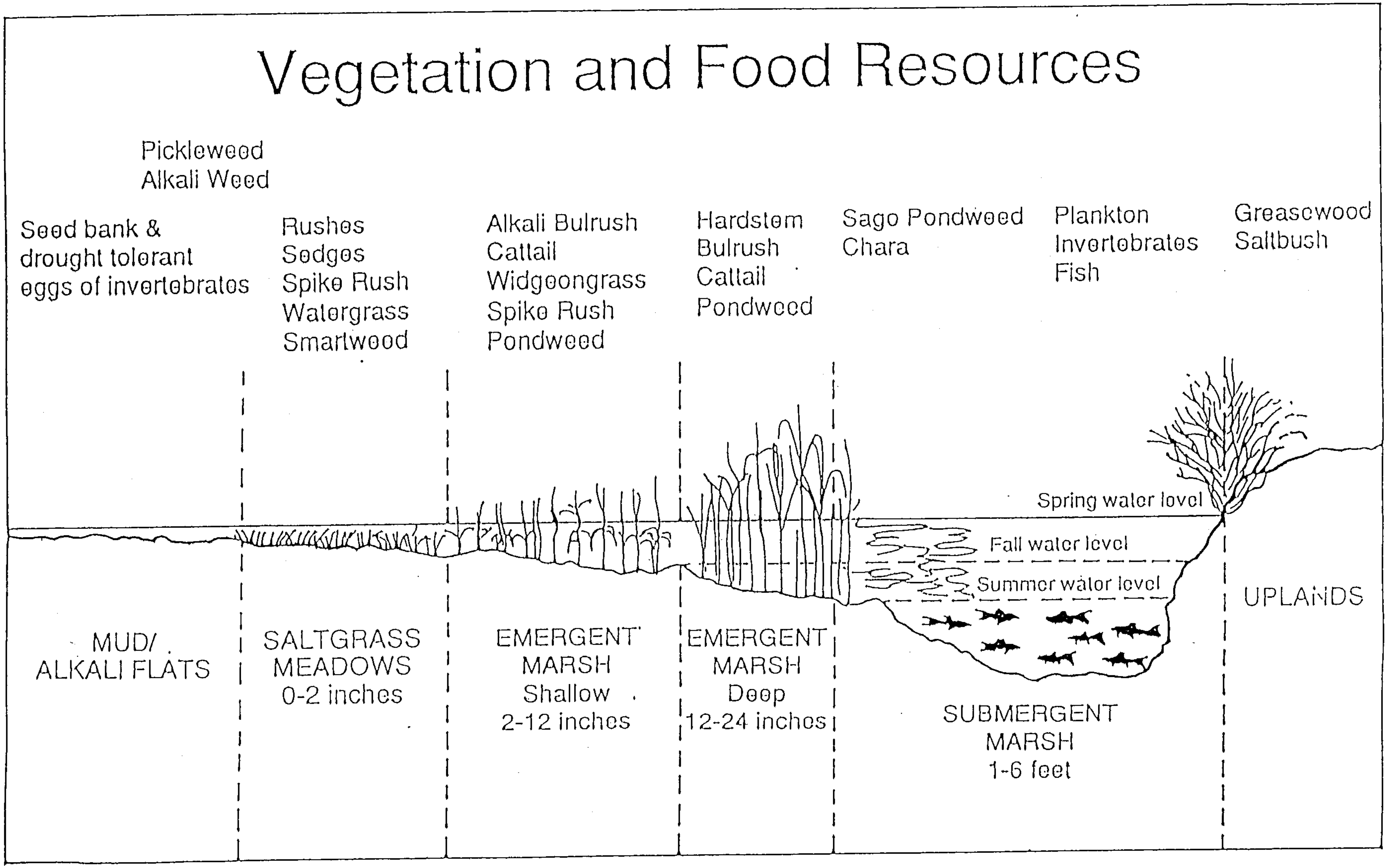

Figure 4. Vegetation and food resources of Great Basin wetlands.

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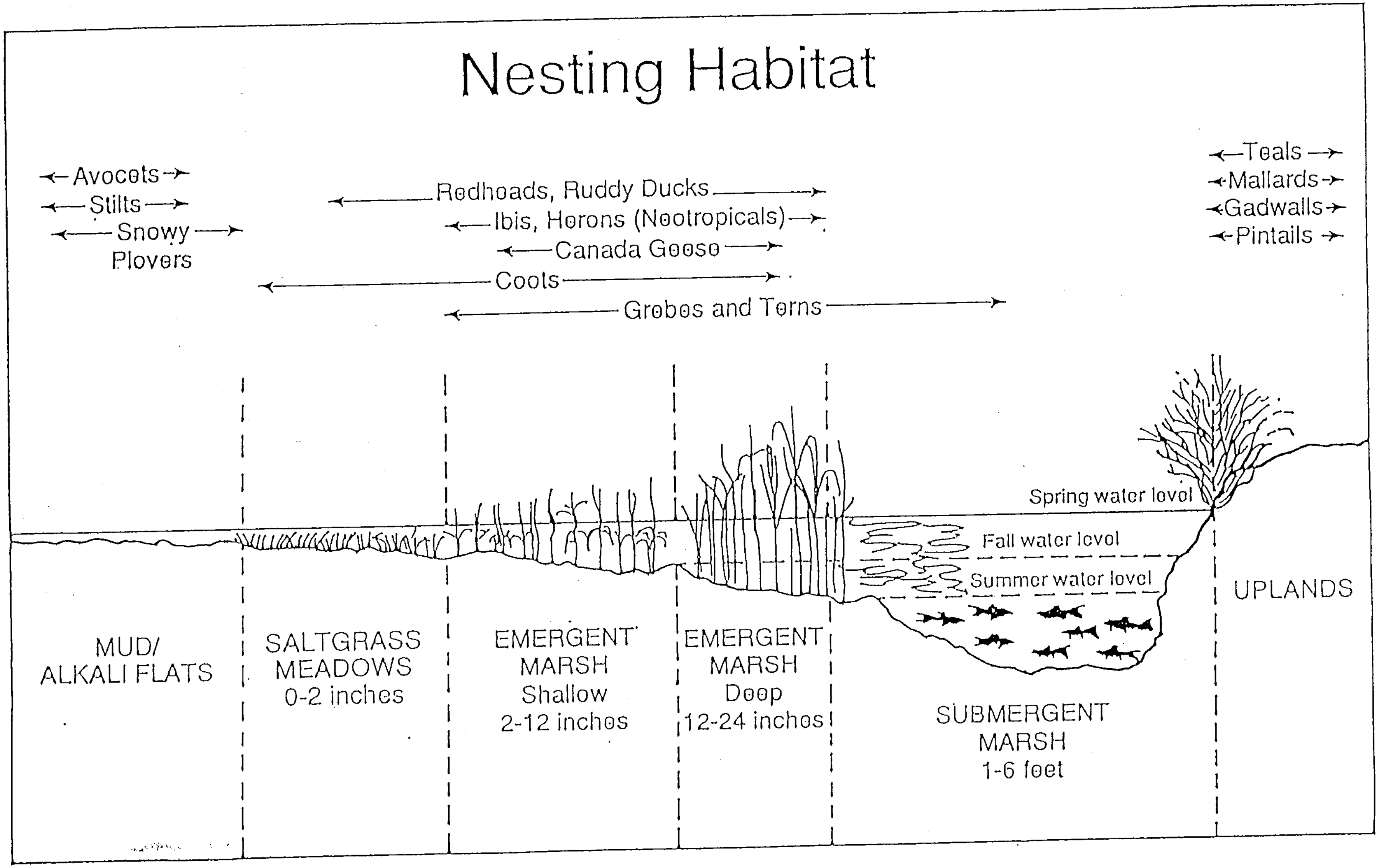

Figure 5. Nesting habitat of Great Basin wetlands.

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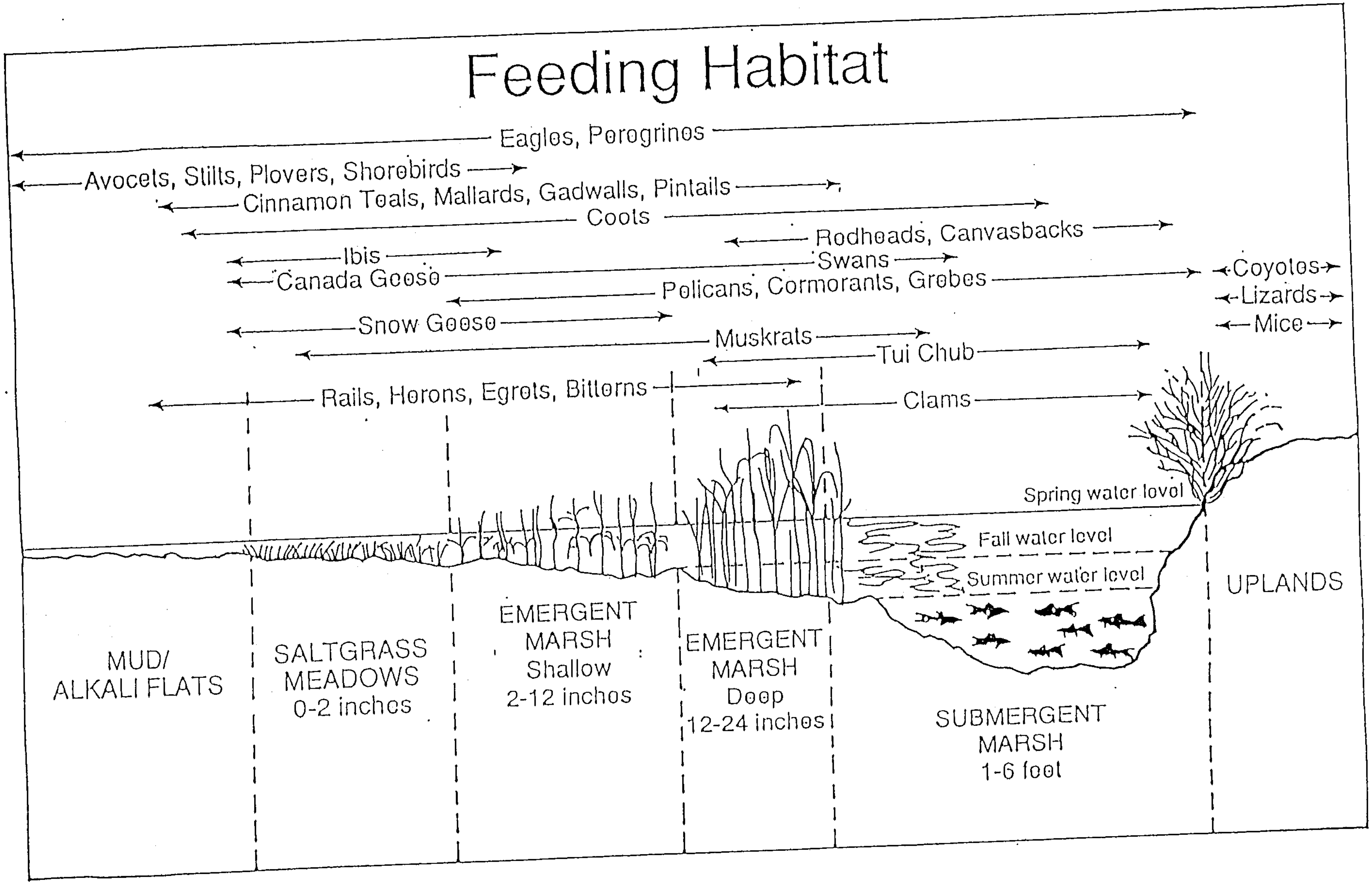

Figure 6. Feeding habitat of Great Basin wetlands.

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was known about the salinity and water depth distributions of important plant species at the Refuge. Table 1 lists conductivity (as a surrogate for salinity) ranges for submergent aquatic vegetation which are found primarily in the submergent marsh habitat type. Table 2 lists the conductivity ranges associated with "moist soil" plants that typically occur on drier sites representing the mud/alkali flats and saltgrass meadow habitat types. However, these plants require moist soil to germinate and will tolerate shallow inundation.

Table 1. Conductivity distribution of submergent and floating aquatic plant species.

Conductivity range (µmhos/cm)		
200-2,000	2,000-10,000	10,000-50,000+
horned pondweed	sago pondweed	widgeongrass
curly pondweed	Western pondweed	chara
<u>Lemna</u>		

Table 2. Conductivity distribution of moist soil plant species.

Conductivity range (µmhos/cm)		
200-2,000	2,000-10,000	10,000-50,000+
saltgrass	saltgrass	saltgrass
watergrass	pickleweed	pickleweed
smartweed	bassia	bassia
kochia	swamp timothy	
swamp timothy	smartweed	

Finally, Table 3 summarizes the distribution of emergent plant species with respect to both water depth and conductivity. These species would occur primarily in the shallow and deep emergent marsh habitat types. Although cattail and hardstem bulrush persist in the intermediate, 2,000-10,000 µmhos/cm conductivity class, they require the fresher water conditions of the 200-2,000 µmhos/cm class to become established.

Table 3. Distribution of emergent plant species by water depth and conductivity.

Water depth (feet)	Conductivity (µmhos/cm)		
	200-2,000	2,000-10,000	10,000-50,000+
0-1	reed arrowhead spike rush cattail alkali bulrush hardstem bulrush rush sedges	cattail alkali bulrush hardstem bulrush	alkali bulrush
1-2	cattail alkali bulrush hardstem bulrush	cattail alkali bulrush hardstem bulrush	alkali bulrush
2-3	cattail hardstem bulrush	cattail hardstem bulrush	

Much of the spatial and temporal pattern of salinity in these marsh areas is produced by the progressive concentration of salts from evapotranspiration. Downstream units tend to have higher concentrations because they are receiving flows that have already been subject to evapotranspiration in upstream units. Similarly, concentrations tend to increase from spring through the summer as water levels and volumes decline because evapotranspiration losses are exceeding inflows of water. Finally intra-unit variations in salinity result from imperfect mixing.

Discussion

The focus of the workshop was on evaluating the utility of existing information and identifying potential new information to support the planning and management decisions facing Stillwater Refuge, rather than producing a definitive analysis of habitat types and vegetation patterns. From this perspective, the development and discussion of Figures 4-6 and Tables 1-3 at the workshop provided substantial insight into how much is known concerning species-habitat relations for the Refuge management units. In particular,

- Habitat preferences are reasonably well defined for a variety of animal species, including the target species (primarily migratory birds) identified in current Refuge objectives.

- Wildlife habitat preferences are expressed in terms of cover types defined in terms of combinations of water depths and vegetation.

- Vegetation differences can be reasonably well predicted by differences in the environmental variables of water depth and salinity, with conductivity and total dissolved solids serving as surrogates of salinity. Complicating factors include preexisting vegetation and the sequence or timing of hydrologic conditions.

- Current management and planning of the marsh systems in the Lahontan Valley is most limited by the ability to forecast the environmental conditions of water depth and salinity that would be created in different units as a result of water management decisions, rather than the ability to relate those environmental conditions to vegetation or to relate the resulting habitat to animal species responses.

Other sources of information about environmental conditions, vegetation, and habitat utilization of Lahontan Valley wetlands include ethnographic studies of historical use and knowledge of marsh resources by native Americans (Fowler 1993; Raven and Elston 1989), published surveys of the area (Billings 1945; Marshall 1949, 1952), and Refuge monitoring records. The biological literature on Lahontan Valley wetlands was considered limited in scope and spatial scale (Nachlinger 1993). Refuge monitoring records are a rich source of data on trends in marsh vegetation, hydrologic and salinity conditions, and wildlife utilization within the Refuge. Deficiencies of the monitoring records include temporal gaps, inconsistent and weakly documented sampling protocols, and their restricted spatial focus of Stillwater Refuge marsh units as opposed to the larger set of Lahontan Valley habitats. A strong argument was made at the workshop that more information on the occurrence and species composition of wetland habitat types in areas outside the Refuge is needed to support the formulation of habitat objectives for the entire 25,000 acres of primary wetlands.

WETLAND MANAGEMENT MODELS

Management of Refuge marshes involves manipulation of inflows, and thus water depths, to management units in order to create or maintain the wetland communities and associated salinity conditions described in the previous section. Given a limit to the water rights the Refuge will be able to acquire in the future, and the complexity of the current water delivery and management system, various wetland models have been proposed to help refuge staff manage the marshes. Workshop participants discussed these models and decided that a water management model was necessary to make best use of available water in the future. Discussions during the workshop helped refine the specifications for such a model. This model might eventually be linked to a wetland vegetation model or a geographic information system (GIS) to predict acreage of different vegetation types flooded during the year.

Water Management Model

In order to better specify the type of water management model required, workshop participants discussed the spatial and temporal resolution of the model, the management actions the user should be able to manipulate in the model, the output variables the model should provide to the user, and the input data required. The following sections summarize participants' preliminary decisions concerning each of these aspects.

Spatial resolution

Spatial resolution involves both the overall area represented by the model and the extent to which that area is subdivided. Although the Refuge currently has management authority only for marsh units within it's boundaries, it was recommended that a water management model represent a larger area encompassing the Refuge, including the Canvasback Gun Club, the Fallon Indian Reservation, and Carson Lake. This area was suggested because of language in the settlement act concerning maintenance of 25,000 acres of primary wetlands and potential expansion of the refuge boundaries. The model should represent individual management units within this area. For the Refuge and the Canvasback Gun Club, these are the units specified in Figure 7. Management units on the Indian Reservation and within Carson Lake will have to be added to this diagram.

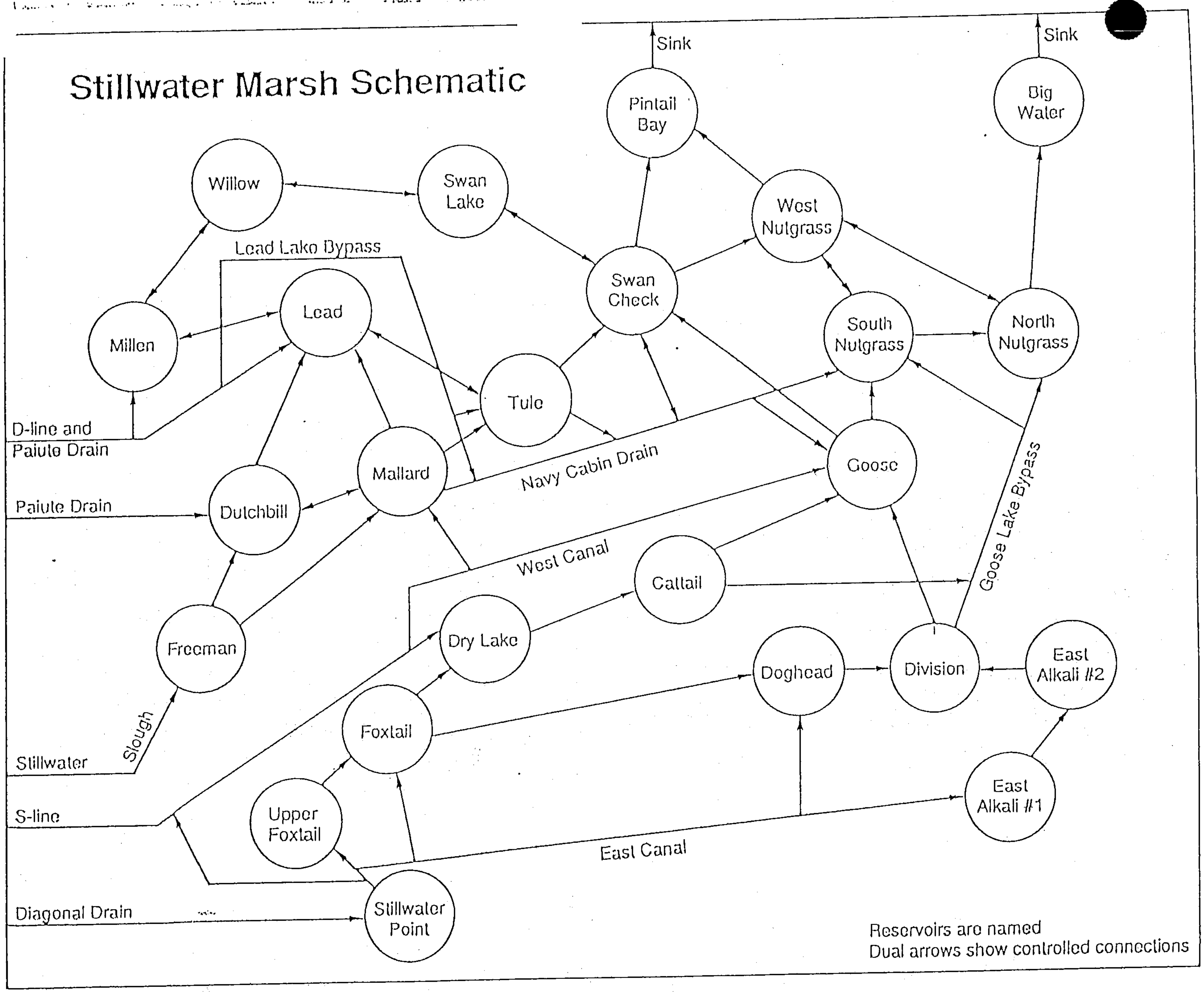

Figure 7. Stillwater Marsh schematic.

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Temporal resolution

Temporal resolution involves both the time frame represented by a run of the model and how often output variables should be calculated during that time frame. The primary purpose of this model would be to help refuge staff develop annual management plans for the various marsh units. Therefore, users should be able to run the model for a one-year time period. However, multiple-year runs should also be possible in order to evaluate longer-term consequences of management decisions.

Participants decided that monthly calculations of output variables would be sufficient to develop and evaluate management plans. However, the model might have to use daily or weekly input variables and calculations to maintain hydrologic integrity (e.g., a calculation based on average monthly evapotranspiration could result in the "loss" of more water than a unit contained during that month).

Output variables

For each management unit, the model should, at a minimum, provide monthly calculations for surface acres flooded, surface elevation, and water depths in specific spatial zones. The water depth in specific spatial zones is especially important because it would allow refuge staff to integrate information concerning wetland plant germination, current vegetation composition, and wildlife habitat needs with predictions of water level changes associated with proposed management actions. For example, knowing when a certain spatial zone will be a mudflat would allow refuge staff to predict the type of vegetation that may germinate in that zone in the coming year. Knowing when existing zones of vegetation will be flooded to different depths would provide information on potential nesting and brood rearing cover. Such depth information would also allow an assessment concerning volume of water used per unit area of habitat created. A water management model that does not consider spatial zones within a unit would not provide adequate information. For example, consider the diagrams of water depths in Figure 8. A model that provided a monthly depth profile for the unit as a whole, rather than for spatial zones, would only be able to tell the user that the surface area flooded 0-1 ft deep was the same in June as it was in May and that the total surface area flooded had decreased. However, refuge staff need to know, for example, that the outer zone was flooded in May but not in June.

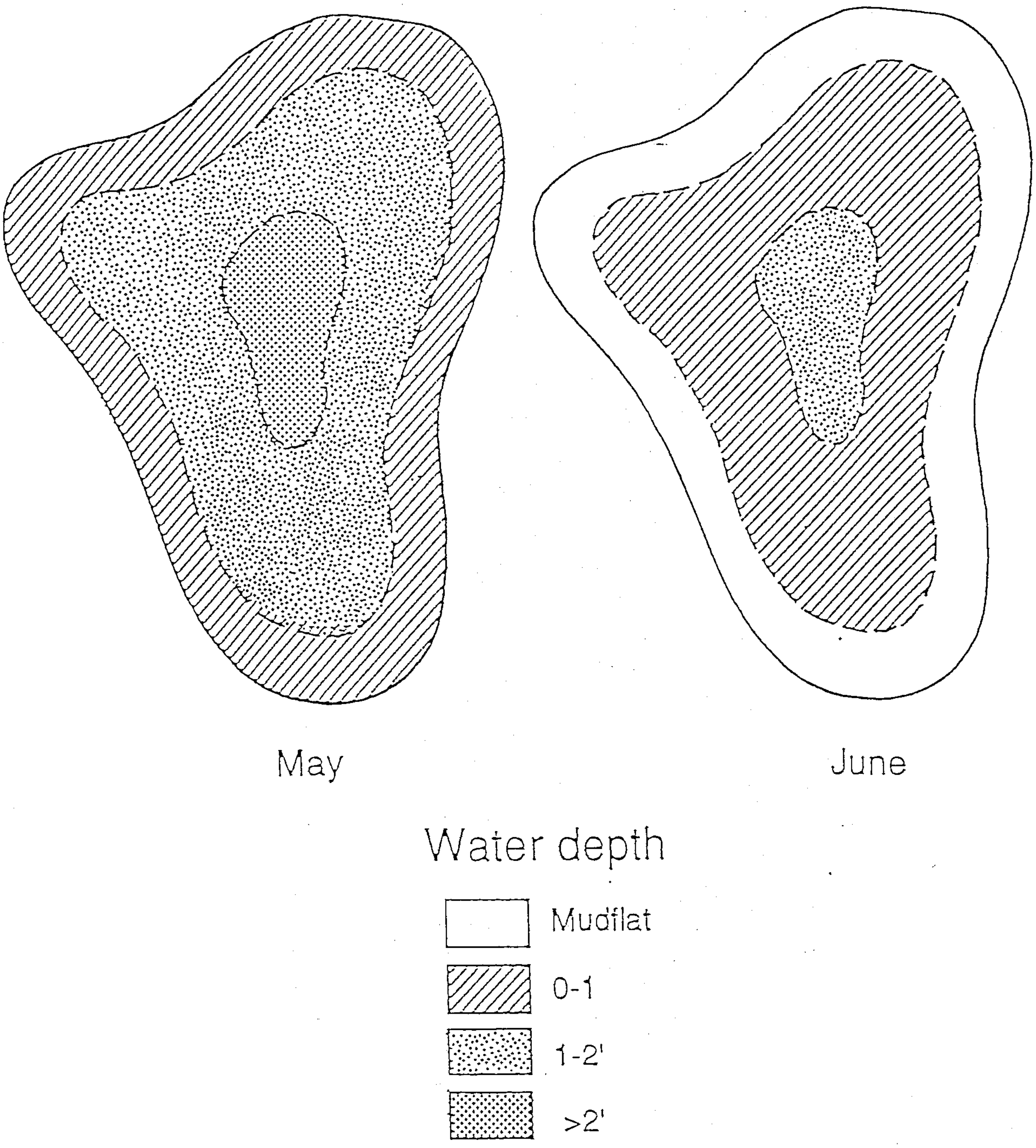

Figure 8. Water depth zones in a hypothetical wetland management unit.

. Several options for providing information concerning water depths in spatial zones were discussed. First, each unit could be subdivided into concentric zones, perhaps based on 6-inch depth increments. Model output would then consist of the average water depth in each of these zones each month, which would be integrated with information on existing vegetation and plant germination requirements by refuge staff. This option should be implemented initially because it is the least costly and uses the same bathymetry information required for other outputs described above. This option might also provide output that could be easily linked to a geographic information system. Second, a vegetation simulation model could be developed that used water depth and TDS information from the water management model to explicitly predict vegetation composition and depth of inundation for concentric bands in each management unit. Such a model could produce output information on acreage/depth for each vegetation community (e.g., acres of cattails flooded 0-1 ft deep, acres of cattails flooded 1-2 ft deep). A final option would be to link output from the water management model to a GIS. The GIS would contain spatial data on vegetation in each unit. Output from the model could be used to display water depth profiles for each unit. By overlaying these two data themes, the GIS could produce estimates of the acres of each vegetation type in each of the water depth classes. While this option may not be implemented initially, care should be taken when developing the water management model to ensure that model output can be easily imported into the GIS and converted into appropriate depth profiles.

The model should also be able to predict average TDS in each management unit. Although TDS gradients develop within management units, it will not be possible to incorporate such complexity in the water management model initially. Instead, the model will assume complete mixing within a unit and conservation of salts (times a factor to crudely account for various losses). If the model results are not adequate, then refinements such as explicitly accounting for salt becoming encrusted on the surface as units dry out, deflation, and seepage losses will be considered. Incorporating a more explicit TDS accounting component, assuming that baseline data exist, would greatly increase the complexity and cost of a wetland management model.

Management actions

The model should allow the user to manipulate the timing, amount, and source of water deliveries to each management unit. This might be implemented by having the user specify target volumes (or surface acres flooded), and perhaps target TDS levels, for each unit for each month of the year. If a unit was below its target volume, or above its TDS target, the model would try to reach the target by "calling for" water deliveries, subject to constraints on remaining water rights as predicted by the Bureau of Reclamation and the Below Lahontan Reservoir hydrology models. If a unit exceeded its target volume, the model would try to spill excess water into ditches or down-gradient management units.

At a minimum, the model should represent the current delivery and management system. It would be nice if the model also provided the capability to close down some existing ditches (as has been proposed based on contaminant issues) or to add a few additional connections (e.g., Diagonal to East Canal).

Input data

Three general categories of input data are needed for this type of model. First, data would be entered by the user for each model run to represent initial conditions and proposed management actions. These data would include volume and TDS for each unit at the beginning of the year; volume and TDS targets for each unit for each month, and the configuration of the water delivery system (i.e., what ditches and connections between units are possible for this model run). Second, basic capacities and characteristics of the units and water management system would be required, but would remain fairly constant unless new construction or dredging was done. These data would include depth/area curves for each unit (depth/volume can be calculated from depth/area), stage/discharge curves for water control structures, capacities of delivery ditches, and monthly evapotranspiration rates by unit or vegetation community. Finally, predictions of monthly water availability would be provided by other hydrologic models and would serve as constraints as the model tries to meet monthly targets.

Hardware Considerations

The wetland management model should be developed so that it is user-friendly and can be run by staff on computers at the Refuge headquarters. While initial work on a water management model (e.g., development of general structure, demonstration of feasibility and utility) should utilize a hardware/software platform that allows for rapid prototyping and development, it is strongly recommended that the final model be delivered on an IBM-compatible platform. If the model is to be linked with a GIS as described above, then the model should contain an option for generating output in a format compatible with the GIS hardware and software. Hardware and software standards for GIS applications in Region 1 are currently being developed.

Data Needs

The wetland management model outlined above is based on a relatively simple mass balance calculation of water in connected units. Inflows of water (precipitation, surface inflow, subsurface inflow) are balanced with outflows (evapotranspiration, surface outflow, subsurface outflow), with change in storage accounting for any difference in inflows and outflows for each unit. The accuracy of the model will depend on how well these inflows and outflows can be estimated. Direct precipitation is a relatively small flow and can probably be reasonably estimated from precipitation records at least for a monthly time step. Assuming surface flows can be accurately estimated from measurements or from the results of water management decisions, the two most critical variables are evapotranspiration and subsurface flow.

Subsurface flow

Subsurface flow is difficult to measure directly and is most easily obtained by difference after the other flows and change in volume have been measured. However, in a modeling context there will have to be some calculation of what subsurface flow would be under various conditions. The most convenient situation would be if subsurface flow is small enough relative to other flows that it could be ignored. The U. S. Geological Survey is currently measuring surface inflows and outflows, change in storage volume, and water tables in adjacent wells for one Refuge management unit. Details of this study were not available at the workshop, but the results may identify the relative importance of subsurface flow or at least suggest a combined estimate of subsurface flow (most likely a net loss) and evapotranspiration.

Evapotranspiration

There are many formulae for modeling the rate of evapotranspiration, ranging from a simple partitioning of an annual total to complex equations incorporating solar radiation, wind speed, cloud cover, humidity, and vegetation. Field measurements consist of 1) a standard pan evaporation station for estimating evaporation from a defined open water surface and 2) difference methods that account for all the other flows and changes in storage and then attribute the residual to evapotranspiration.

The very high rates of evapotranspiration in the Lahontan Valley make evapotranspiration an extremely important part of a water budget calculation. Accordingly, workshop participants recommended that standard pan evaporation stations be established at Stillwater Refuge and Carson Lake. The nearest existing station has a somewhat different microclimate than the marsh sites and there has been a continuing controversy about the appropriateness of using off-site pan evaporation data. This seemed an issue that could be resolved with some relatively straightforward measurements. If a reasonable relation could be developed among stations there would be no need to continue to maintain all the stations over the long term.

However, accurate pan evaporation measurements or estimates do not solve the whole problem. Pan evaporation data must be combined with some type of water budget monitoring of actual units in order to estimate the factor or factors relating pan evaporation to the actual evapotranspiration from real marsh units. Practically, such factors may also end up incorporating some part of net subsurface flow as well because of the difficulty of independently measuring these rates in the field with difference-based methods.

Bathymetry

Good bathymetry, or topographic data, on the marsh units is important to a water budget model for several reasons. This is the basic information used to relate the volume of water in a unit to water surface elevation, or stage, and to the surface area of the unit. Stage-volume curves allow volume changes to be tracked from the easily obtained stage readings and convert model predictions of volume to water depth, which is a more meaningful habitat variable. Area-volume curves relate volume to wetted surface area, which is also an important habitat variable. Wetted surface area is also a critical variable in the water balance calculation itself because of its influence on total evapotranspiration losses. Rates of evapotranspiration are estimated as a quantity of water per area. This rate is then multiplied by the respective area of open water or wetted vegetation to obtain the total loss from the unit for some time interval. Thus the shape of the area-volume curve can have a substantial influence on the water balance of a unit by determining whether a given volume is spread over a large area and subject to high total evapotranspiration losses, or concentrated in a smaller, deeper area and subject to proportionally lower evapotranspiration losses. These general considerations are especially important in the Lahontan Valley marshes with high rates of evapotranspiration and quite shallow topographic relief.

The Refuge has detailed, current (1987) topographic maps prepared by photogrammetry using surveyed control points and bench marks. The data are limited, though, because areas under water when the photography was taken are depicted as flat with no underwater elevations. These missing data areas need to be filled in and similar topographic data need to be developed for Carson Lake and Fallon Indian Reservation. Extreme low water conditions greatly simplify this job.

There are several methods that could be used to obtain the additional elevation data. Photogrammetry from new photography flown when the units are dry is one approach. Ground surveying with a level and tape, or a total station surveying instrument, is another approach. Global Positioning System (GPS) instruments might be used to establish horizontal (x,y) locations, but would probably not be accurate enough for elevation (z). A variant of this approach is to use the water surface as a level and determine the horizontal locations of the water's edge by surveying, GPS, or photography. The Refuge has experimented with this approach using a GPS instrument. The Refuge also has a laser level instrument and has used it to survey several cross sections. An experienced land surveyor, or engineer, should be consulted to help choose the most efficient approach.

The additional elevation data should be at least as detailed as the existing topographic maps. Furthermore, there are considerable advantages to having georeferenced (map or coordinate based) elevation data. It is possible to derive area-volume curves by methods that do not also produce elevation contours with accurate horizontal (x,y) locations. Although such area-volume curves would be adequate for the water balance calculation, they would not support any analysis of which spatial areas were under how much water. Given the possible linkage of output from the wetland management water model to a GIS, it seems prudent to base the area-volume relations on solid georeferenced elevation data to avoid additional surveying that might be required for the GIS.

Monitoring

Calibration, refinement, and verification of the wetland management model will require field measurement. Selected flows, water surface elevations, and water surface areas must be measured over time and compared to model output in order to calibrate estimates of actual evapotranspiration and subsurface flow, and to verify that stage-volume and area-volume curves are sufficiently accurate. The proposed approach to modeling TDS is a severe simplification and is best viewed as an estimate of the "salt concentration potential" in different units. These model estimates need to be compared to field measurements of conductivity or salinity. The importance of continued data collection to verify and recalibrate the hydrologic relations and parameters cannot be overstated.

The Refuge has a continuing program of monitoring vegetation and wildlife use. This program should be continued and perhaps expanded to make it as consistent as possible with the spatial form of model outputs. The wetland management model will not directly predict vegetation or wildlife use. Thus, management decisions will have to be based on a combination of water depths and areas predicted by the water management model, and vegetation and wildlife information obtained from future monitoring as well as existing records. As such, it would also be useful to synthesize existing reports and understanding concerning water management of Refuge, Fallon Reservation, and Canvasback Gun Club marshes and Carson Lake. A GIS would be an excellent framework for integrating model predictions, field observations of hydrologic conditions, and existing monitoring programs focused on vegetation and wildlife use.

VALLEY-WIDE CONSIDERATIONS

One of the provisions of the 1990 Water Rights Settlement Act is for the Secretary of the Interior to consider, by 1997, possible expansion of the Refuge boundaries. This mandate, along with a general concern about how well the Refuge and other primary wetlands represent and protect the biodiversity of the Lahontan Valley, stimulated a proposal by The Nature Conservancy to conduct a valley-wide survey and classification of wetland vegetation. This effort would involve a one-time vegetation survey of 100-150 plots conducted over 3-6 weeks. Concomitantly, environmental variables (e.g., soil type, slope, aspect, elevation, landform, water depth, and soil and water chemistry) would be measured at the site visit or determined from existing data sources such as soil surveys. Classification analyses of the patterns of plant species occurrence and correlations with the environmental variables would identify distinct communities or cover types with an indication of the environmental gradients associated with each.

One of the more useful results of the workshop was a clarification of what would and would not be accomplished by such a study. Given the temporal variability of important environmental variables determining vegetation (e.g., water depth), the temporal variability in marsh vegetation at any site, and the detail of vegetation differences important to wildlife, this type of extensive, one-time survey would likely not produce information on vegetation responses to environmental conditions that was sufficiently detailed to contribute to short-term water management decisions or a wetland management model. Furthermore, for practical reasons an initial effort would focus on plant communities. However, a classification of plant communities would provide a solid foundation for later consideration of other components of biodiversity.

The principal benefit of a valley-wide survey and classification would be to place the Refuge and other primary wetlands in a larger biodiversity context. It would define important components of biodiversity that are (or are not) represented and protected within the 25,000 acres of primary wetlands specified in the settlement act and would therefore be useful for establishing habitat objectives and for evaluating possible expansion of the Refuge boundaries. This type of coarse, landscape-level analysis is similar in many respects to the predictive model of prehistoric land-use developed for the Stillwater Wildlife Management Area and currently being expanded to a larger area (Raven and Elston 1989; Raven 1990). That model predicts the distribution and composition of archaeological sites over a grid of 1-km^2 cells, using variables such as soil type. With some attention to the underlying data themes, such as soil type, it might be possible to integrate the results of a vegetation survey with the archaeological model in a common GIS. This would provide a powerful tool for large scale planning activities such as acquisition. It would also provide a foundation for adding additional landscape-level spatial variables including other components of biodiversity (e.g., vertebrate distributions) and possibly contributions of various areas to water quality.

CONCLUSIONS AND RECOMMENDED ACTIONS

The objectives of the workshop described in this report were to evaluate existing information concerning wetland communities in the Lahontan Valley, discuss wetland management models that might be developed to help manage the 25,000 acres of primary wetlands specified in the settlement act, and identify future information and monitoring needs to support wetland management decisions in general and the management model in particular. The conclusions and recommendations of workshop participants are summarized below.

Refuge Objectives and Wetland Communities

1. Wildlife habitat preferences, expressed in terms of cover types defined by combinations of water depths and vegetation, are reasonably well known for a variety of animal species, including target species identified in current Refuge objectives.

2. Differences in vegetation communities can be reasonably well predicted by differences in water depth and salinity.

3. Current management and planning of marsh management units is most limited by the ability to forecast water depth and salinity conditions that would be created in different management units as a result of water management decisions, rather than the ability to relate those environmental conditions to vegetation or to relate the resulting habitat to animal species responses.

4. A wetland management model would help forecast the water depth and salinity conditions resulting from management actions as described above. A GIS would allow these forecasts and existing information concerning vegetation communities and wildlife habitat preferences to be better utilized to support management decisions. Specific recommendations concerning models and a GIS are listed below.

Wetland Management Models

1. A wetland management model should be developed that includes the 25,000 acres of primary wetlands specified in the settlement act (the Refuge, Canvasback Gun Club, Fallon Indian Reservation, Carson Lake). For each marsh or management unit, the model should provide monthly output on surface acres flooded, surface elevation, water depths in defined spatial zones, and average TDS. The model should allow the user to manipulate the timing, amount, and source of water deliveries to each marsh or management unit and should provide the capability to make single-year model runs to help develop annual management plans or multiple-year runs to evaluate longer-term consequences of management decisions.

2. An existing wetland management model provides many of the capabilities described above. This model could be expanded to include the Fallon Indian Reservation and Carson Lake and modified to predict water depths in specified spatial zones within marshes or management units.

3. Development and calibration of a wetland management model will require additional data collection and continued monitoring. The primary needs are to:

   a. Establish pan evaporation stations and conduct water budget monitoring for selected wetland management units.

   b. Finish topographic mapping of refuge management units and develop topographic maps for Carson Lake and the Fallon Indian Reservation. The elevation data should be at least as detailed as the existing topographic maps and there would be significant advantages to developing georeferenced elevation data for eventual inclusion in a GIS.

   c. Establish monitoring programs for selected flows, water surface elevation and area, and water salinity. Current Refuge monitoring of vegetation and wildlife use should be continued or expanded to make it as consistent as possible with the spatial form of model outputs and a GIS.

4. Existing information and understanding concerning wetland management at the Refuge, Canvasback Gun Club, Fallon Indian Reservation, and Carson Lake should be synthesized.

Valley-wide Considerations

1. Wetland plant communities throughout the Lahontan Valley should be inventoried and classified. While such a study would not likely produce information sufficiently detailed to contribute to short-term wetland management decisions, it would define important components of biodiversity that are or are not protected within the 25,000 acres of primary wetlands specified in the settlement act. Such information would be very useful for evaluating possible expansion of the Refuge boundaries.

2. With some attention to the underlying data themes, it might be possible to integrate the results of the wetland plant community survey with the archaeological model in a common GIS. Future monitoring of marsh conditions, vegetation, and wildlife use for the 25,000 acres of primary wetlands could also be incorporated into this GIS and used to support future management decisions.

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Marshall, D.B. 1949. Stillwater Wildlife Management Area, Churchill County, Nevada: A biological investigation of the Stillwater Wildlife Management Area, June 7, 1949 to September 16, 1949. U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 50 pp + maps.

Marshall, D.B. 1952. Habitat types of the Stillwater Marsh and their value to nesting ducks with reference to future management. U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 29 pp. + 11 maps and tables.

Nachlinger, J. 1993. Stillwater Marsh and Lahontan Valley wetlands literature review. Unpublished report, The Nature Conservancy, Reno, NV 27 pp.

Raven, C. 1990. Prehistoric human geography in the Carson Desert, Part II: Archaeological field tests of model predictions. U.S. Fish and Wildlife Service, Cultural Resources Series Number 4.

Raven, C., and R. Elston. 1989. Prehistoric human geography in the Carson Desert, Part I: A predictive model of land-use in the Stillwater Wildlife Management Area. U.S. Fish and Wildlife Service, Cultural Resources Series Number 3.

U.S. Fish and Wildlife Service. 1952. Narrative report: Stillwater Wildlife Management Area, January - April 1952. Unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV.

Stillwater Marsh

and

Lahontan Valley Wetlands

Literature Review

by

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STILLWATER MARSH and LAHONTAN VALLEY WETLANDS
LITERATURE REVIEW

Contents

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LITERATURE REVIEW

Executive Summary

A review of known literature on Lahontan Valley marshlands was made by The Nature Conservancy in preparation for the Stillwater Water Management Analysis Scoping Workshop held in Fallon, Nevada, 17-19 November 1992. The objectives of the literature review were to evaluate the existing information for its value to three levels of management needs, including: 1) day-to-day marsh management operations and modelling at Stillwater National Wildlife Refuge; 2) coordinated marsh management of three primary wetland areas—Stillwater Refuge, Carson Lake, and Fallon Indian Reservation; and 3) an assessment of biological diversity for the entire Lahontan Valley.

The interest in evaluating the literature for information on the biological diversity of the Lahontan Valley is two-fold. Section 206 of Public Law 101-618 directs management of Stillwater National Wildlife Refuge for purposes that include maintaining and restoring natural biological diversity, and providing for the conservation and management of fish and wildlife and their habitats. In addition, the law authorizes recommendations of any boundary revisions that may be appropriate to carry out those management purposes. Consequently, it was of interest to know whether the existing information on biodiversity is adequate to carry out the mandates.

Several sources were used to obtain literature citations and copies of the literature for review. By far the most useful source of information on Lahontan Valley marshlands came from files and staff at the Stillwater National Wildlife Refuge. Other sources included: Nevada Department of Wildlife; U.S. Fish and Wildlife Service (Reno Enhancement Office, Portland Regional Office, and National Wetlands Research Center, LA); Nevada Natural Heritage Program; and the Department of Navy (Fallon Naval Air Station). Some sources of information, such as the University of Nevada, Reno and the Soil Conservation Service, could not be pursued because of project time-constraints. Accordingly, the review is not exhaustive.

Ninety-four documents were obtained and reviewed for information on marsh management and biodiversity of Lahontan Valley wetlands. An annotated bibliography of these sources follows. It is arranged chronologically within four time-periods: pre-Newlands project; early Newlands project; early refuge development; and, post-refuge development.

Literature from the pre-Newlands project time period (1845-1898) are either descriptive accounts or scientific notes by early explorers and scientists. These accounts are too general to draw conclusions regarding the specific distributions and abundances of plants, animals, or communities in the Lahontan Valley at that time. Almost all were written after the mid-1800s westward migration to California and early settlement in western Nevada.

The Lahontan Valley already had been altered by large-scale human disturbances (livestock grazing, water diversions, marshland burning, conversion of natural communities to croplands). As a result, no detailed pre-disturbance baseline of the marshlands exists and all subsequent literature relates to modified landscapes to varying degrees.

The early Newlands project literature of the marshlands (1908-1937) is scant. During this time period, development of the first Federal irrigation project was viewed as positive progress and little consideration of impacts to the environment were made. The few reports provide lists or very brief descriptions of plant communities and animals. They are of little value for determining the current status and changes in biodiversity, and they are of no value to marsh management and modelling efforts.

Literature from the period of early development of the Stillwater National Wildlife Refuge (1943-1957) was written during construction of the refuge. Many of these studies focused on narrating general marsh conditions and monitoring the responses of aquatic vegetation and waterfowl to those conditions. They are the first relatively detailed accounts of aquatic marshlands and include the first good descriptions of vegetation and plant associations. Concerns about the losses of wetlands and changes in species composition of communities surface in this literature. Although many environmental variables were not monitored, the studies provide much needed information for marsh management. They also contribute information on some changes in the area's biological diversity.

The period of post-development of the Stillwater Refuge (1959-present) provides the greatest quantity and the highest quality of data. Extensive data collection and monitoring in aquatic and submergent marshland communities was done primarily at the refuge, but also at other marshlands in the valley. More detailed information on environmental variables, such as turbidity, salinity, and water depths, were systematically collected. A wealth of information for managing and modelling aquatic and submergent marshlands for waterbird production is provided. However, most other marshland types were not studied. Some species information for tall emergent communities is given, but essentially no data for short emergents, graminoid meadows, grasslands, or alkali scrub communities are detailed. Species lists of common plants and animals can be gleaned from the literature, but data on community compositions, plant associations, structure, and changes in these attributes through time are lacking. Little information for managing and modelling other marshlands as habitat for other avifauna is available. Little information on the distributions and abundances of invertebrates and small mammals is known. The literature documents the decreased trend in acreage of wetlands, but it lacks detailed data to thoroughly evaluate the past and present diversity of biological resources.

A fundamental understanding of the components of natural biological diversity of the Lahontan Valley is needed to properly manage the Stillwater National Wildlife Refuge as well as to evaluate marshlands that should be added to or eliminated from its boundaries. The existing literature provides some of that understanding, but many gaps in the data exist. Refuge management and boundary evaluation would benefit from a more systematic inventory of Lahontan Valley marshlands.

Annotated Bibliography

I. Pre-Newlands Project Literature:

Spence, M.L. and D. Jackson (eds.) 1973. The expeditions of John Charles Fremont. Volume 2, Supplement, proceedings of the court-martial. University of Illinois Press, Urbana, IL.

In 1845, Fremont's party camped at North Carson Lake (Stillwater Marsh). The outlet is described as having banks 8-10 feet high with willow growth. About 8 miles below is a large marsh hidden by sand hills and with "extremely disagreeable waters". Moving southeast to Carson Lake, the border of the lake was edged for 30-40 yards in width with a thick growth of bulrushes. "It is a very pretty sheet of water; various kinds of fowl in abundance. The greatest length is about 11 miles. The lake is bounded on the west by a low range of mountains; about midway on the western side a stream [Carson River] enters it. Slightly timbered; probably cottonwood."

Simpson, J.H. 1876. Report of explorations across the Great Basin of the Territory of Utah for a direct wagon-route from Camp Floyd to Genoa, in Carson Valley, 1859. U.S. Army, Engineer Department, Washington, D.C. Reprinted by University of Nevada Press, Reno, NV, 1983.

A descriptive narrative of the sink of Carson Valley in 1859. The Carson River to the northwest is quite distinctly marked by a line of green cottonwoods. The alluvial bottom of Carson Lake is extensive and rich, with a luxuriant growth of rushes, although somewhat alkaline in places toward the southern portion. The outlet is about 50 feet wide and 3-4 feet deep, flowing northward with a strong current. Birds are frequent. The lake is filled with fish, local Paiutes are drying chubs and mullet. The east shore of Carson Lake is margined with rushes, the shores covered with muscle-shells [sic]. South half of lake is white with alkali.

DeQuille, D. (W. Wright). 1963. Washoe Rambles. Westernlore Press, Los Angeles, CA.

Journeyed from Virginia City through the Lahontan Valley to the Stillwater Range to explore the geology and mining potential of the area in 1863. Anecdotal writings about the area include 1) water overflowed from Carson Lake into Stillwater Slough; 2) at the mouth of (Stillwater) slough, a lake was bordered by "very extensive meadows of excellent grass"; 3) marshes with bul-rushes were noted and Indians had baskets filled with "the seeds of a species of water-dock and various grasses growing in the marshes near the mouth of the slough"; 4) there was a lake in the Carson Sink.

Monroe, E.B. 1867. Plat map of Carson Lake. On file at Stillwater National Wildlife Refuge, Fallon, NV. 1 plate.

Indicates about 14 square miles of "Tule Swamp" fringing Carson Lake on north and east margins up to 1/4 mile wide, and on northwest, extending up the floodplain of the South Fork Carson River for several miles. Indicates that present Stillwater Marsh area "overflowed" in an area of 32 square miles. A marginal annotation notes "extensive Tule Swamps" for the mouth of Old River at the southern margin of Carson Sink, but does not indicate so on map.

According to Raven and Elston (1989), Monroe's "Tule Swamp" at Carson Lake is marked as "tule marsh" on the 1876 Wheeler Survey map, while Stillwater marsh area is marked as "tule swamp".

Russell, I.C. 1885. Geological history of Lake Lahontan, a quaternary lake of northwestern Nevada. U.S. Geological Survey, Washington, DC. 288 pp.

Prior to 1862, the Carson River flowed to South Carson Lake (along the south fork). The 1862 high water flows bifurcated to both South and North Carson lakes, with the slough between the two areas. Ranchers had cut an overflow channel to the desert, which later created "New River" during the flood of 1862. Accounts from 1859 and 1866 are compared: in 1859, Captain Simpson reported the slough to be 50 feet wide and 3-4 feet deep; in 1866, Lieutenant Birnie reported waters sluggish with scarcely perceptible flow. Russell describes Carson Lake as 40 square miles, while the sink was dessicated because all water had been diverted to South Carson Lake. Various branches of the river may be traced by lines of vivid green cottonwood trees that mark the river courses. His 40 sq. mi. description of Carson Lake is used as the basis for later historical reconstructions of the wetlands.

Bailey, V. 1898. Physiography, Nevada: Carson Lake Valley (Wadsworth, Ragtown, and Stillwater). Handwritten notes. 8 May 1898. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 69, Folder 14, Washington, D.C. 3 pp.

Describes the physiography and general vegetation of the Carson Sink (in vicinity of Fallon NWR) from a 3-day field trip. Mentions 8 vegetation types: 1) slope soils washed of salt and soda with other than alkaline plants, 2) flat valley bottoms loaded with salt and soda, baked mud, where rain water settles, and devoid of plants, 3) flat bottom of valley with scattered low shrubs of Sarcobatus, Atriplex, Suaeda, and Tetradymia, 4) extensive sand dunes, 5) clay mounds with Sarcobatus near lowest mud flats, 6) extensive shallow lake/tule swamp of the valley bottom, 7) saltgrass/sedges/tules associated with lake/swamp, and 8) narrow and broken line of cottonwoods along the Carson River. Mentions 3 disturbance factors in place: 1) livestock grazing—many thousand head of stock wintering in marsh anad foraging on saltgrass/sedges/tules; 2) and 3) water diversion and crop conversion—ranches along river with ditches for the irrigation of alfalfa and fruit crops.

Bailey, V. 1898. Nevada: Stillwater to Ione, Birds. Handwritten notes, 10-14 May 1898. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 70, Folder 16, Washington, D.C. 6 pp.

Lists 42 species of birds with notes on relative abundances and habitats. Most were noted in the desert mountains rather than in the lowlands of interest.

Bailey, V. and H.C. Oberholser. 1898. Nevada: Carson Sink Valley, Wadsworth, Ragtown, and Stillwater, Mammals. Handwritten notes, 10-14 May 1898. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 69, Folder 13, Washington, D.C. 8 pp.

Lists 20 species of mammals with notes on relative abundances and habitats. Most were noted in wetland communities. Mentions that tules had been burned.

Bailey, V. and H.C. Oberholser. 1898. Nevada: Stillwater to Ione, via Osobb, Lodi and Lone Valleys, Mammals. Handwritten notes, 10-14 May 1898. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 69, Folder 13, Washington, D.C. 6 pp.

Lists 19 species of mammals with notes on relative abundances and habitats. Most were noted in the desert mountains rather than in the lowlands of interest.

II. Early-Newlands Project Literature:

Fisher, A.K. 1908. Fallon, Nevada: Birds. Handwritten notes, 7-13 and 21-22 August 1908. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 69, Folder 21, Washington, D.C. 3 pp.

Lists 40 species of birds with very brief notes on relative abundances.

Piper, S.E. 1908. Nevada: Fallon, Mammals. Handwritten notes, 17-27 January and 26 March-15 April 1908. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 70, Folder 19, Washington, D.C. 7 pp.

Lists 21 species of mammals with notes on relative abundances and habitats in the vicinity of Fallon.

Hall, E.R. 1925. Nevada Report, Mammals, Churchill County, Nevada. Handwritten notes, 11-18 May 1925. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 70, Folder 3, Washington, D.C. 14 pp.

Lists 21 species of mammals with notes on relative abundances and habitats.

Kreager, P.T. and Jr. Forester. 1929. Fallon migratory bird refuge—acquisition examination report. Unpublished manuscript, Smithsonian Institution Archives. 2 pp. + map.

Map shows 14,000 ac of wetlands at the terminus of the Carson River—at Fallon NWR.

Sperry, C.C. 1929. Report on Carson Sink (Churchill Co.) Nevada: Its duck food resources and value as a federal migratory bird refuge site. Unpublished report, Smithsonian Institute Archives, Washington, D.C. 3 pp. + maps.

Describes the vegetation, in an area of 4 townships centered near present day Fallon NWR, primarily by dominants, and provides some qualitative comments on abundances. Discusses 8 marsh types (alkali bulrush, tule, three-square bulrush, common cattail, cattail/alkali bulrush, common spikerush, mix of spikerush/cattail/alkali bulrush, acicular spikerush), 4 aquatic types (sago, horned pondweed, water-milfoil, coontail, with algae common throughout open water), 1 riparian type (willow and poplar with white sweet clover, cattail, juncus, chrysothamnus, mustard, saltgrass), and 4 sink shore types (sagebrush, iodine bush, pickleweed, saltgrass). Mentions birds and qualitative abundances. Frogs and clams were common, snails and aquatic insect life were abundant. Concluded that area is of high value for a refuge.

Winsor, L.M., G.E. Holman, and B. McBride. 1937. Report on Stillwater area Carson Sinks project, Churchill County, Nevada (Report covering plan of proposed development, Stillwater area Carson Sinks migratory waterfowl refuge, Churchill County, Nevada). U.S. Department of Agriculture, Bureau of Biological Survey, Fallon, NV. 30 pp. + maps.

Purpose of report was to address problems with TCID proposal to create a migratory waterfowl refuge by leasing 30,000 ac to the Bureau of Biological Survey. TCID would provide land and water and receive pasturage, while the Bureau would pay to construct the 9 mile water delivery ditch from Stillwater Slough and get the refuge. The main problem was the location of the proposed ditch to convey water to the refuge. Problems addressed included a dispute by Freeman Ranch that TCID does not have the right to divert water from the slough; the gun clubs and private hunters object to closing the refuge to hunting; and need for more engineering data to determine amount of area that proposed canal could cover. No vegetation or management information, but appendices include flow, precipitation, and pan evaporation data. Average annual pan evaporation data for 1908-1934 = 58.63 in - 4.9 in annual precipitation / 1.3 (conversion factor for pan) = 41.33 in or 3.44 ft.

III. Stillwater Refuge Early Development Literature:

Savage, J.C. 1943. U.S. Fish and Wildlife Service memorandum regarding waterfowl breeding condition in western Nevada during June, 1943. Smithsonian Institution Archives, Record Unit 7176, U.S. Fish and Wildlife Service, 1860-1961, Field Reports, Box 71, Washington, D.C. 3 pp.

Water conditions were found to be excellent in all areas reached, and for Stillwater Marsh in particular, it was in better condition than in the past twenty years. The water area is very large and the shore line very extensive. Waterfowl population was quite satisfactory. The redhead population is worthy of note—it formed about 40% of entire number of birds in area. Broods were observed, but it was noted that later observation would show many more young birds. No specific numbers were given.

Billings, W.D. 1945. The plant associations of the Carson Desert region, western Nevada. Butler University Botanical Studies 7:89-123.

Detailed descriptions of 15 plant associations listing dominants and characteristic plant associates in the region. Includes descriptive information on environmental variables, such as soils and relative salinity. Eight associations are upland types: little greasewood-shadscale; winter fat: dalea; big greasewood; big greasewood-shadscale; rabbitbrush; iodine bush; and sagebrush. Seven are riparian/wetland types: samphire; alkali grass; saltgrass; bulrush; cat-tail; spike-rush; and cottonwood.

Anonymous. 1947-1950. Raw data forms. Unpublished data, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 13 pp.

Raw data for various stations in Lahontan Valley (Stillwater Diversion Canal, Kent Lake Drain, Sagouspe Dam, Stillwater Slough, Upper Paiute Drain, and Stillwater Point Reservoir) including data on electrical conductivity, total dissolved solids, cations, and anions (chloride, boron, and others). Also, water clarity forms for some stations with notes on plant growth.

Marshall, D.B. 1949. Stillwater Wildlife Management Area, Churchill County, Nevada: A biological investigation of the Stillwater Wildlife Management Area, June 7, 1949 to September 16, 1949. U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 50 pp. + maps.

First descriptive biological report produced for refuge just 1 year after establishment and during construction of area. Physical descriptions (water, turbidity, acreages, soils, pH) are brief. States that "annual evaporation is 5 feet", a much larger figure than 1937 report by Winsor and others. Discusses 7 subjective vegetation types (essentially areas in the refuge), 6 are open water or management units, and 1 is a desert type. Describes their predominant plant communities (11 total) as emergents

(4), shoreline (2), aquatic (3) and desert (2). Lists plant species, with a focus on dominants, and describes their distributions, with 13 emergents, 12 aquatics, 11 shoreline, and 8 desert species. Lists 10 fishes; 7 are game and 3 are non-game species. Lists 8 herptiles; 2 are amphibians and 6 are reptiles. Lists 97 birds with 14 only from Canvasback Club and 9 only from the Stillwater Range; most common are water/marsh birds (10), ducks/geese (13), shorebirds (17), and passerines (16). Gives population numbers for waterfowl. Finally, lists 8 mammals.

Map of cover types based on aerial photos (taken by Navy during War) is at scale of about 2.2 in = 1 mi. Includes 4 emergent types in color: narrowleaf cattail (Typha domingensis and T. angustifolia together); alkali bulrush; hardstem bulrush; saltgrass. Also includes locations and abundances of 4 aquatic types: sago, coontail, wigeongrass, muskgrass. Abundances are 3 subjective categories of scattered, moderate, or heavy growth.

Anonymous [probably D.B. Marshall]. 1951. An investigation of the factors affecting the growth of aquatic plants on the Stillwater Wildlife Management Area, 24 September 1951. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 5 pp.

Purpose of study was to determine factors prohibiting the growth of waterfowl food plants—assumed turbidity was limiting factor. Studied turbidity of various ponds at the marsh. Small ponds were clearest. Six factors contributed to turbidity: 1) silt character; 2) current; 3) turbulence at structures; 4) wave action in larger ponds; 5) lack of bottom or bank cover; 6) carp activity. Sago distribution not closely related to turbidity, so studied soil characteristics. Sago usually present on soils with greater mineral content, but also present in some ponds with muck bottoms. Concluded that periodic desiccation may promote sago growth.

Anonymous [probably D.B. Marshall]. 1952 or 1953. Map of cover types of Stillwater Wildlife Management Area. Unpublished map, on file at Stillwater National Wildlife Refuge, Fallon, NV. 1 p.

Map has about 15, color-coded, cover types, such as, flooded, cattail, bulrush, saltgrass, greasewood, alkali weed, and other dominants; includes boundaries of management units/ponds.

Marshall, D.B. 1952. Habitat types of the Stillwater Marsh and their value to nesting ducks with reference to future management. U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 29 pp. + 11 maps and tables.

Two-year study evaluated various habitat types for nesting ducks at Stillwater. Again, includes brief physical descriptions. Discusses the value of 5 broad types and 17 specific types of habitats based on water duration and species presence and absence. Group 1, with 2 types, are long-lived permanent water bodies with no open shore edge and no sago—poorest nesting habitats. Group 2, with 2 types, are permanent water bodies for 5-10 years with sago—poor habitats. Group 3, with 6 types, are areas subject to late summer drying, all support sago—good habitats. Group 4, with 6 types (1 intermediate with G3), are areas flooded in high water years only and may have sago—best habitats in general. Group "5", 1 type, is flooded alkali flats with no plants—good habitat. Gives total acres, edge mileage, and duck numbers of types. Provides information for management of waterfowl (puddle and diving ducks) habitat types. Concludes that with proper water management (periodic drying and seasonal draw-down) can produce more ducks. Histograms and photographs included.

U.S. Fish and Wildlife Service. 1952. Narrative report: Stillwater Wildlife Management Area, January-April, 1952. Unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV.

Peggy Wheat, a local archaeologist, interviewed Alice Steve and Woozie [Wuzzie] George, local Paiute Indians determined to be qualified observers. Dave Marshall, refuge biologist, helped and spent three days with them verifying plant and animal identifications. All plants had individual names, except for submergents which had one general name. Alice and Wuzzie provided descriptions of the area and compared the vegetation around 1900 to current (1952) vegetation: hardstem bulrush—1600 ac vs. 800 ac now; cattail—1300 ac vs. 3800 ac now; alkali bulrush—1900 ac vs. 1200 ac now. Mentions that the Indians created Indian Lakes in recent times by damming the Carson River and diverting water into an excavated channel.

Marshall, D.B. 1953. Vegetational changes in the Nutgrass unit of the Stillwater Marsh. Special report, U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 4 pp.

Describes the acreages of cattail, hardstem bulrush, alkali bulrush, open water (with sago and wigeongrass), and island (with bare ground and saltgrass) in the unit on June 1951. Then recounted management actions: 7/51—dried; 10/51—flooded; 2/52—dry except for deepest areas; 6/52—flooded and dry in 1 month; 1/53—shoots burned; 1/53—shallow flooded deeper areas; 6/53—flooded; 7/53—reevaluated acreages of vegetation types and found much less cattail and hardstem, more open water which was very clear and free of fish, lots of cattail seedlings; 7/53—drained to kill cattail seedlings; 8/53— cattail seedlings dead. Discusses management implications.

Giles, L.W. 1953. Loss of cattail and bulrush in the Stillwater Marsh outside the Nutgrass unit. Special report, U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 7 pp.

Compares acreages of tall emergents in refuge units between 1951 and 1953, and showed a 23% loss on refuge and 48% loss in open hunting areas. Discusses factors including 1) muskrat grazing responsible for hardstem bulrush losses; 2) lack of fire (Canvasback Club burned annually in spring and has more green emergents and less die-off than refuge); also related are possible chemical changes in the soil and water from accumulation of organic matter and loss of water circulation; 3) flooding from higher water levels; 4) disease, redspots and out-of-season color changes to bright yellow noted; 5) increased alkalinity from increased capillary action. Mentions that cattle ranchers regularly burned marsh prior to refuge establishment. Refuge management objectives were directed toward elimination of extensive cattail growth to create better puddle duck nesting habitat, but they noted that this reduced muskrat habitat. Concluded that spring burning is essential and completion of water control is important to grow sago.

Hazeltine, I.B. 1954. Inventory of wetlands for the state of Nevada. U.S. Department of Interior, Fish and Wildlife Service, Portland, Oregon.

This was part of a nationwide survey to locate and tabulate by habitat type the important wetlands and estimate their current value for waterfowl. Much information was collected from FWS and NV Fish and Game Commission offices, then field examination was made to assess current conditions. Wetland types and waterfowl uses were classified. Of the 11 overall types of wetlands 4 were identified for Churchill County: 1) inland fresh, seasonally flooded basins or flats; 9) inland saline, saline flats; 10) inland saline, saline marshes; and 11) inland saline, open saline water.

Sutherland, D.E. 1957. Estimated water requirements, Stillwater Wildlife Management Area. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 7 pp. + 12 tables and 2 appendices.

Purpose of report was to provide estimates of water requirements needed to maintain various wetlands. Wetlands were defined as open water, marsh (emergents), saltgrass, and irrigated pasture. Canvasback Club was included because it was considered integral to marsh. Computations assumed that ground seepage was zero. Open water evaporation estimated by pan evaporation method was 54.9 in annually (x .94 pan coeff - 4.95 annual ppt = 46.6 in or 3.9 ft water required). Other wetlands were computed by Blaney-Criddle method using climate data, yielding 45.9 in (3.8 ft) for emergents, 24.5 in (2 ft) for saltgrass, and 24.5 in (2 ft) for pastures. Using estimates of current acreages, water requirements were calculated as 84,890 ac-ft for developed wetlands, 34,003 ac-ft for natural marshes, and 1,144 ac-ft for pastures, which totals 120,037 ac-ft for 34,706 ac cover. An additional 34,253 ac-ft is needed for proposed developments.

IV. Stillwater Refuge Post-Development Literature:

Stillwater Aquatic Surveys: 1959-present

Purpose of series is to collect composition, frequency, and density data on submergent vegetation in the Stillwater Wildlife Management Area and compare with previous surveys in an effort to evaluate management. Data are reported by primary marsh units with some other observations recorded. Sampling methods and timing vary throughout report series and make it difficult to compare between years. Very detailed data on aquatic and submergent dominant species with exact distributions and qualitative abundances (later reports attempted to quantify tonnage of aquatics, but stopped because of intensity of sampling). Valuable series for marsh management information.

Hein, D. 1959. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1959. U.S. Fish and Wildlife Service, unpublished report.

The 1959 report by D. Hein, which is the first in the series of surveys, is missing from refuge files.

Wiseman, G.L. 1960. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1960. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 12 pp.

[Note: No report for 1961 was written because severe drought conditions prevailed and no aquatic plant survey was made.]

Wiseman, G.L. 1962. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1962. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 4 pp. + tables and maps.

Schwabenland, P.A. 1963. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1963. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 30 pp.

Schwabenland, P.A. 1964. Emergent vegetation growth in 1963 on Stillwater Wildlife Management Area. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 4 pp.

Ekedahl, V. 1965. Habitat inventory techniques. Unpublished U.S. government memorandum to refuge managers from the regional refuge supervisor on habitat inventories—aquatic plant surveys. 7 pp.

Documents a standard methodology for selecting sampling sites and sampling

submergent vegetation, and gives a quick review of statistical analysis of simple random sampling data. The methodology was used for awhile, but was later abandoned.

Schwabenland, P.A. 1965. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1964. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 41 pp.

Schwabenland, P.A. 1966. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1965. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 47 pp.

Napier, L.D. 1967. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1966. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 39 pp.

Napier, L.D. 1968. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1967. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 42 pp.

Napier, L.D. 1969. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1968. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 50 pp.

Napier, L.D. No date [1970?]. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1969. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 43 pp.

Paullin, D.G. 1970. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1970. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 45 pp.

Napier, L.D. 1972a. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1971. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 4 pp.

No systematic aquatic plant survey was made in 1971. The report is a descriptive narrative only.

Napier, L.D. 1972b. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1972. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 35 pp.

[Note: 1973-1977 Stillwater aquatic plant surveys were conducted as part of the SWMA wildlife management study series, see below.]

U.S. Fish and Wildlife Service. No date. Open files on vegetation studies at Stillwater Wildlife Management Area. Field notes, on file at Stillwater National Wildlife Refuge, Fallon, NV.

These appear to be the raw field notes for the binder reports summarizing wildlife habitat conditions and production in the mid to late 1970s.

Anonymous. 1978. Stillwater Wildlife Management Area, Fallon, Nevada: Stillwater aquatic plant survey—1978. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 4 pp.

[Note: No report for 1979 was written.]

Ross, M.A. 1980. Stillwater Wildlife Management Area, Fallon, Nevada: Waterfowl habitat survey—1980. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 14 pp.

Brastrup, G.D. 1981. Stillwater Wildlife Management Area, Fallon, Nevada: Annual aquatic plant survey and waterfowl habitat survey—1981. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 32 pp.

Gerdes, G.L. 1982. Stillwater Wildlife Management Area, Fallon, Nevada: Submerged aquatic plant survey—1982. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 39 pp.

Gerdes, G.L. 1983. Stillwater Wildlife Management Area, Fallon, Nevada: Submerged aquatic plant survey—1983. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 51 pp.

Gerdes, G.L. 1984. Stillwater Wildlife Management Area, Fallon, Nevada: Submerged aquatic plant survey—1984. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 50 pp.

Gerdes, G.L. 1985. Stillwater Wildlife Management Area, Fallon, Nevada: Submerged aquatic plant survey—1985. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 22 pp.

Gerdes, G.L. 1986. Stillwater Wildlife Management Area, Fallon, Nevada: Submerged aquatic plant survey—1986. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 24 pp.

Bowman, T. 1987. Stillwater Wildlife Management Area and vicinity, Fallon, Nevada: Stillwater aquatic plant survey—1987. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 56 pp.

Bowman, T. 1989. Stillwater Wildlife Management Area and vicinity, Fallon, Nevada: Aquatic plant and waterfowl habitat survey—1988. Unpublished paper, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 48 pp.

This is the last summary report for the refuge to date. From 1990 on, data are summarized in refuge.annual reports only.

U.S. Fish and Wildlife Service. 1991. Table 5. Comparison of wetland acres and aquatic plant vegetation of SNWR units from 1988-1991. U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 1 p.

Table is a summary from the refuge narratives written in annual yearbooks.

Canvasback Club Waterfowl Habitat Surveys: 1960-1965, 1972, 1986

Purpose of series is to determine present waterfowl habitat conditions on the Canvasback Club to understand its present and potential value to breeding waterfowl of the Pacific Flyway and to analyze current management. Objective of management is to maintain habitat for the best duck production possible and provide best attraction during migration for optimal hunting opportunity. Aquatic plant species and physical conditions are reported by water areas/management units. Plants were sampled with a rake in random fashion. Water depth, light penetration, bottom character (mud depth) were measured while presence of carp was visually estimated. Some notes on emergents at pond margins are given. Later reports had new observers so could not compare with past years of subjective observations. Used a 5 category scale of abundance ratings which was more definitive than past subjective modifiers.

Wiseman, G.L. 1960. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 29 pp. + 22 maps and tables.

Wiseman, G.L. 1961. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 4 pp. + 6 maps and tables.

Wiseman, G.L. 1962. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 8 pp. + 9 maps and tables.

Schwabenland, P.A. 1963. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 15 pp.

Schwabenland, P.A. 1964. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 19 pp.

Worden, L.H. 1965. Waterfowl habitat survey, Canvasback Gun Club. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 19 pp.

Osugi, C.T. 1973a. Waterfowl habitat survey, Canvasback Gun Club, 1972. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 11 pp.

Essentially the same type of survey as in the 1960s. Methodology changed. Also measured water depth and salinity.

Gerdes, G.L. 1986. Canvasback Gun Club, submerged aquatic plant survey—1986. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 8 pp.

Stillwater WMA Wildlife Management Studies: 1972-1977

Series is six valley-wide monitoring studies conducted by the refuge. Objectives of these studies are to inventory the wetland habitats and wildlife use, record public use, monitor physical (habitat types, acreages, water levels, TDS concentrations) changes at SWMA, determine if habitats can absorb displaced wildlife and public use, document losses, and ultimately use the data to request direct allocation of water for SWMA. Data are given by 11 wetland units (Fernley WMA, Massie and Mahala Sloughs, Soda Lake, Old River, Sheckler, Fallon Farmland, Carson Lake, Harmon, S-Line, Canvasback Gun Club, and Stillwater Refuge). Gives precipitation and temperature records, describes water level fluctuations and measured salinity by unit. Sampled aquatic plant production (submergents and emergents) and provides fairly qualitative abundances. Does not indicate when sampling was done, and methodologies varied between years. Gives waterfowl population and production by area and discusses other marsh birds, raptors, mammals, and fisheries. Gives recreational use and economic benefits (grazing and muskrat production). Tables give data by unit. States that statistical analyses were impossible because appropriate number of samples could not be taken.

Osugi, C.T. 1973. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson Irrigation District, Nevada. Progress Report No. 1 (1972). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 45 pp. + 6 maps.

1972 data were considered to be the baseline because this was last year that TCID was allotted their full 406,000 ac-ft.

Osugi, C.T. 1974. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson Irrigation District, Nevada. Progress Report No. 2 (1973). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 49 pp. + 6 maps.

Osugi, C.T. and M.J. Barber 1976. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson Irrigation District, Nevada. Progress Report No. 3 (1974). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 29 pp.

Barber, M.J. 1976. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson Irrigation District, Nevada. Progress Report No. 4 (1975). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 24 pp.

Barber, M.J. 1977. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson

Irrigation District, Nevada. Progress Report No. 5 (1976). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 31 pp.

Barber, M.J. 1978. Stillwater Wildlife Management Area: Report of wildlife management study; monitoring program of wildlife habitat and associated use in the Truckee-Carson Irrigation District, Nevada. Progress Report No. 6 (1977). U.S. Department of Interior, Fish and Wildlife Service, Fallon, NV. 31 pp.

6th and last report in series. Gives update on recent legal controversies. Provides tables and histograms with direct comparisons of data to 1972 baseline year. Decreased water deliveries and drought resulted in one of poorest years for wildlife and wetlands. Provides a summary table for all 6 years of study. Based on an average water supply (388,000 ac-ft) future losses (at Stillwater, Fernley, and Carson Lake) are projected, and it is concluded that they would not be absorbed (by smaller wetland areas), but would be ultimately lost. States that studies are discontinued until a final court ruling on water rights and distribution is reached.

Carson Lake Studies

Saake, N. 1970. Map of Carson Lake. Unpublished map, on file with Nevada Department of Wildlife, Fallon, NV.

Base is a 1970 aerial photo of Carson Lake on which emergent vegetation was mapped for 12 July 1970. Shows areas of alkali bulrush, hardstem bulrush, and cattail.

Alcorn, R. 1971. Wildlife usage of the Carson Lake area—Churchill County, Nevada. Unpublished paper, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 9 pp.

States that Carson Lake is both economically and ecologically important. Hunting and grazing provide economic benefits, while its value to game and non-game birds provide ecological benefits, that are critical for some species of non-game migrants. Included is a partial checklist of birds of marsh areas with notes on abundances.

Turner, R.J. 1980. The status and nongame values of Carson Lake, Nevada. Cal-Neva Wildlife Transactions: 6-10.

Made a literature review of recent (1972-1978) bird habitat at Carson Lake, during which time both the lake and bird habitat decreased in acreage. He conducted surveys in 1979 to observe nongame use by marsh and shorebirds. Nongame use and production, with an emphasis on white-faced ibis, proportionally declined with decreases in wetland habitat. Grazing impacts included reducing food and cover, and destroying nesting structures. Did not follow through will all intentions of the study.

Gerdes, G.L. 1986. Carson Lake, submerged aquatic plant survey, Fallon, Nevada. U.S. Fish and Wildlife Service, unpublished report on file at Stillwater National Wildlife Refuge, Fallon, NV. 13 pp.

This monitoring report was done as part of the valley-wide project. Ponds and ditches at Carson Lake were surveyed for plant species composition, relative abundance, water depth, visibility, and salinity.

Other Studies and Reviews:

Macklin, R., E.D. Stetson, and H.R. Leach. 1960. Wildlife and fishery use made of drainage waters in Nevada. Unpublished paper, on file at Stillwater National Wildlife Refuge, Fallon, NV. 5 pp. + 2 tables.

Purpose of 3-day trip was to document wildlife and fishery use of drainage water in the Carson Sink. Most important waterfowl food production is in newly developed areas because cattail, tule, and carp are controlled by water management. Mentions types of waterfowl, other game, and game fish using area. Includes a table of water quality sampling data with electrical conductivity, TDS, and temperatures, and comments include fish species presence. Valuable only for game fish management.

Watson, R.C. 1964. Stillwater Wildlife Management Area, Fallon, Nevada: program task force report. Unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV. 25 pp.

Purpose of report was to present data to support the values of SWMA and make an argument for considering it in future planning of the Washoe project. Much discussion of FWS contribution towards development of area for wildlife and recreational uses. Revised Sutherland's (1957) evapotranspiration figures slightly upwards and revised the annual water requirements to 133,693 ac-ft including the Canvasback Club. Documents beneficial water use at Stillwater for 7 water years. Value of wetlands argued in terms of importance to Pacific Flyway as a stop-over, high waterfowl production, and high hunter use. Mentions that salt cedar has invaded in recent years, and now is receiving extensive control management, but until control is done on watershed basis, Lahontan reservoir will continue to be an annual seed source. Concludes that the Washoe project will leave no water for Stillwater, and recreational needs of Tahoe-Reno-Sparks area have not been planned for. Recommends that the Washoe project plans to provide water to Stillwater, that Carson Lake be acquired and managed by the Bureau of Sport Fisheries and Wildlife, and that the Canvasback Club be acquired so return flows are more efficiently used.

U.S. Fish and Wildlife Service. 1968. Stillwater Wildlife Management Area, Anaho Island NWR, Fallon NWR: refuge narrative report, calendar year, 1968. Unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV.

Report qualitatively compares waterfowl food and cover in various areas at SWMA with previous year's better production.

Betterment Studies Work Group. 1970. Study of Lahontan Valley wildlife areas; Phase I, reconnaissance. Pyramid Lake Task Force, unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV. 8 pp.

Purpose of reconnaissance was to determine waterfowl use in the Lahontan Valley (Carson Sink, Carson Lake, Stillwater Marsh areas). They used planimetry to determine acreages available for waterfowl use. Consumptive use of water was estimated with the Blaney-Criddle method. They also evaluated water use for grazing management.

Betterment Studies Work Group. 1971. Study of Lahontan Valley wildlife areas; Phase II, evaluation of the effect of loss of water for use by waterfowl and other wildlife in the Lahontan Valley. Pyramid Lake Task Force, unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV. 26 pp. + appendix.

Purpose of phase II was to evaluate the effect of reduced water supplies on waterfowl and to recommend ways of offsetting these effects. For various water supply scenarios, they determine acreages of wetland habitats, which units would be taken out of use, reductions of waterfowl production, and reductions of waterfowl use days, but do not explain how figures were derived. They recommend that prime water be available at reduced flows, that FWS consider purchasing water rights (possibly the Canvasback Club), and that upstream storage facilities be constructed to help mitigate impacts.

Evans, C. 1983. Stillwater Wildlife Management Area, Fallon, Nevada: Waterfowl nesting at Stillwater marsh in relation to predation and habitat factors affecting nest site selection. Unpublished paper, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 44 pp. + appendix.

Purpose of study was to evaluate nest success of waterfowl in relation to predation and nest site selection. Nest success was high for redheads, poor for cinnamon teal, gadwall, and other species (pintail, mallard, northern shoveler, and ruddy duck). Predation by ravens was almost exclusive cause of nest losses. Dabbling duck nests were concentrated in small areas of habitat and were vulnerable to high predation. Spring flooding in 1983 reduced availability of nesting habitat. Concludes that nesting habitat improvement may best increase long term waterfowl production.

U.S. Fish and Wildlife Service. 1986. The effects of federal programs on wetlands in Nevada. Unpublished report, U.S. Fish and Wildlife Service, Great Basin Complex, Reno, NV. 46 pp.

Evaluates the effects of federal programs (excessive livestock grazing, easements for diversion structures, and herbicide application on private lands) on various wetlands, including riparian and wet meadow wetlands and palustrine emergent and lacustrine wetlands. States that Nevada's palustrine emergent and lacustrine wetlands are different than those in more mesic environments because they are situated at the termini of closed basins where flow-through is infrequent, and salts and heavy metals accumulate. Because the region was settled early by homesteaders, there is little

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information on the wetlands prior to activities that disturbed them. Estimates the historical and present extent of wetlands using the 5 ac-ft evaporation figure from a Humboldt River study (FWS 1981). Discusses dynamic nature of wetlands, stating that acreages fluctuate annually and monthly depending upon water availability and weather. Discusses the impacts of Newlands project on Lahontan Valley wetlands and future vulnerability in the context of Truckee River and Pyramid Lake needs and makes recommendations accordingly.

Thompson, S. and B. Hallock. 1988. Draft wetland analysis for FEIS: Newlands project operating criteria and procedures, draft record of decision. Unpublished memorandum of U.S. Department of Interior, Fish and Wildlife Service, on file at Stillwater National Wildlife Refuge, Fallon, NV. 148 pp.

SNWR biologists draft response to the Newlands OCAP draft record of decision. Used regression analysis to determine wetlands losses. Discussed water quality and quantity impacts to vegetation, fisheries, waterfowl and shorebirds, and TES species.

Thompson, S.P. and K.L. Merritt. 1988. Western Nevada wetlands: history and current status. Nevada Public Affairs Review, pp. 40-45, University of Nevada, Reno, NV.

Basic review of pre-settlement conditions, reclamation, and 4 areas (Winnemucca NWR, Fallon NWR, Stillwater WMA, and Carson Lake). Calls for protection of the remaining wetlands.

Lamp, R.E. 1989. Monitoring the effects of military air operations at Naval Air Station Fallon on the biota of Nevada. Nevada Department of Wildlife, Reno, NV. Unpublished report, on file at Naval Air Station Fallon, NV. 90 pp.

Study addresses the impacts of air operations to wildlife and associated habitat in the Lahontan Valley and outlying areas. Results for game species indicate that bighorn sheep, mule deer, and sage grouse were minimally impacted, no conclusions for antelope, and chukar partridge were sensitive to low overflight. Migratory birds (bald eagles, snow geese, green-wing teal, pintail, widgeon, and long-billed dowitchers were very sensitive to low overflight. Nesting birds (Swainson's hawk, golden eagle, cinnamon teal, mallard, gadwall, American avocet, great blue heron, double-crested cormorant, western grebe, and eared grebe) habituated to aircraft activity, but may contribute to production stresses. Recommends continued monitoring.

Raven, C. and R.G. Elston. 1989. Prehistoric human geography in the Carson Desert; Part I: A predictive model of land-use in the Stillwater Wildlife Management Area. Cultural Resource Series No. 3, U.S. Department of Interior, Fish and Wildlife Service, Portland, OR. 183 pp.

The model uses facts on the distributions of water and soils to predict biotic (plant and animal) responses and human responses to those resources. Gives an extensive summary of historic water conditions in Lahontan Valley and a good description of marsh dynamics and conditions relative to water conditions. Considerable discussion of the soil mapping units and range sites/ecological sites, leading to habitat types is given. The 3rd order soil survey is basis of work and may be at too great a scale to accurately predict habitat types (see for instance the distribution of GB wild rye grass). Descriptions of all habitat types are given, without much refinement of marsh types.

Raven, C. 1990. Prehistoric human geography in the Carson Desert; Part II: Archaeological field tests of model predictions. Cultural Resource Series No. 4, U.S. Department of Interior, Fish and Wildlife Service, Portland, OR. 143 pp.

The model of prehistoric land use in the Carson Desert is tested against a sample of surface archaeological record. Model predictions are largely supported, however, some aspects of the model were challenged and this led to revision of habitat types and behavioral assumptions. Habitat types of 53 sample units were changed, two types were collapsed within other habitat types, and a playa habitat type was further divided to render better predictions. Overall, a decent model.

Department of Navy. 1990. Geothermal energy development, Naval Air Station Fallon. Volume I, programmatic environmental impact statement. Geothermal Program Office, unpublished report, on file at Naval Air Station, Fallon, NV. 213 pp.

Includes descriptions of plant communities based on aerial photo interpretation, existing literature, and some field work. Report discusses 2 federally endangered raptors, 5 category 2 bird candidates for federal listing, and 4 category 3C plants.

Anglin, R. 1990. Draft, History of Lahontan Valley Wetlands. Unpublished paper, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 8 pp. + addendum.

Paper begins with a review of the Great Basin and ancient Lake Lahontan. Discusses the Carson River, its flows and channel changes, and its termination in the Carson Sink and Lahontan Valley wetlands. Natural dynamics of Great Basin wetlands are reviewed and importance of drying cycles are stressed. Habitat types in the wetlands are noted with an example of an extreme "boom/bust cycle". A salinity "model" of the wetlands is presented.

Kerley, L., G.A. Ekechukwu, and C.A. Janik. 1990. A history of water quality and wetland changes at the termini of the Carson and the Truckee rivers, Nevada. U.S. Department of Interior, Fish and Wildlife Service, Reno Field Station, Reno, NV. 27 pp.

Purpose of paper is to reconstruct hydrological and ecological conditions in the

Lahontan Valley prior to human intervention. Used historic flows in the Carson River and I. Russell's 1882 estimated (maximum) size of Carson Lake to determine size of wetlands in the valley. Range of wetland acreage estimated at 42,500-122,500 ac.

Yardas, D. 1991. Restoring endangered ecosystems: the Truckee-Carson water rights settlement. Unpublished manuscript, on file at Stillwater National Wildlife Refuge, Fallon, NV. 16 pp.

Paper provides an overview of the 1990 Truckee-Carson Settlement Act (PL 101-618) and its restoration mandates. It focuses on authorities related to improved water management, efficiency, and allocation. Several key implementation concerns and unresolved issues are discussed. Restoration of the Pyramid Lake ecosystem and maintenance of an average of 25,000 ac of primary wetland habitat in the Lahontan Valley are considered key components. Water management issues discussed include changes in reservoir operation, acquisitions for Lahontan Valley wetlands, acquisitions for Pyramid Lake, conservation and enhanced water-use efficiency, water banking, and effluent reuse. Additional restoration opportunities are discussed: expansion of Newlands project purposes, riparian habitat restoration on the lower Truckee, funding for fisheries management, restoration of fallowed land, drainage control for improved water quality, changes in eligibility criteria, compensating purchases of water rights, and development of mitigation agreements. Adverse effects of third-party interests address considerations under State law, established water rights, O & M reimbursements, ground water recharge, and socio-economic effects. Adequate funding will be secured by general appropriations, state cost sharing, and private-sector contributions. Unresolved issues include conflict between Pyramid Lake Tribe and TCID, recoupment, acreage base of active and inactive rights, diversion criteria, water banking opportunities, acquisition limits, and socio-economic effects.

Anglin, R. and G. Shellhorn. 1992. Great Basin Wetlands, a concept paper. Unpublished paper, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 5 pp.

This is a rewritten version of Anglin (1990) with much of the same information.

Janik, C.A. and L.L. Kerley. 1992. Draft, Estimated historical wetland conditions. Unpublished report, on file at Stillwater National Wildlife Refuge, Fallon, NV. 21 pp.

This is an updated version of Kerley, et al. 1990. Very similar, although some numbers changed, and the range of wetland acreage fluctuation decreased. The historical size of wetlands, water quality, vegetation, and wildlife are described from postulated information from existing records, reports by early explorers, and archaeological findings. The effects of irrigation drainage on Stillwater Marsh and Carson Lake are evaluated from the reconstructed historic scenario.

Historic, unregulated Carson River flows are estimated as 412,400 ac-ft. Historic wetland acreages are estimated at 27,000 for Carson Lake and 55,500 for Stillwater for a total of 82,500 ac of wetlands—assumes 5 ac-ft needed to maintain 1 ac/yr wetlands. This estimate probably fluctuated as much as 20,000 ac (24%), but there is no discussion where this figure was derived.

Goin, P., R. Dawson, and J.M. Winter (eds.). 1992. Dividing desert waters. Nevada Public Affairs Review, Number 1. Publication of the Senator Alan Bible Center for Applied Research, University of Nevada, Reno. 80 pp.

This issue addresses the Truckee and Carson river systems problems with photography and written essays by 11 authors for a popular audience. Separate chapters on diverse topics include: The Truckee-Carson-Pyramid Lake Settlement Act and Pyramid Lake; Beaver Believers; The Newlands Project: Crime or National Commitment; Pyramid Lake: The Tonic of Wilderness; Nevada's Unique Wildlife Oasis; and, Stillwater: Its Friends and Neighbors.

Studies with Focus on Environmental Variables:

Clyde-Criddle-Woodward, Inc. 1971. Report on water use improvement study of Truckee-Carson River basin. Unpublished report to U.S. Bureau of Reclamation, on file at Stillwater National Wildlife Refuge, Fallon, NV. 11 pp. + 11 appendices.

Purpose of report is to evaluate existing water uses on the Truckee and Carson rivers and determine if additional water could be salvaged, by what means, and at what cost. The water users and TCID have strived for good and efficient water management but opportunity for improvement exists. Improvements include 1) reducing operating spills through automation of structures and centralizing control of water; 2) reducing reservoir evaporation by reducing their size or eliminating some; 3) reducing seepage by lining canals, improving O and M and eliminating aquatic weeds; 4) changing methods of delivery and application; and 5) changes in Lahontan Reservoir. These improvements will negatively impact SWMA, but some impacts can be mitigated. Report provides good background description of surface water flow in the project, physical setting, ground water, and soils. Sources of information not cited. Appendices provide figures for monthly evaporation rate from Lahontan water surface (total annual evap. = 4.62 ft), and estimated consumptive use of water on lands in the Fallon area (total annual evapo-transpiration by dense phreatophytes = 4.83 ft, and by open water = 4 ft).

Glancy, P.A. and T.L. Katzer. 1976. Water Resources, Reconnaissance Series Report 59. U.S. Department of Interior, Geological Survey, Carson City, NV. 126 pp.

Discusses water resources of the Carson River Basin with particular reference to ground water resources. Estimates ground water storage in Lahontan Valley at 8M ac-ft and may be able to use ground water to supplement surface water flow. Further studies needed to determine water quality, quantity, and location of resource. Estimated average annual evaporation at about 4 ft/yr and up to 6 ft/yr.

Green, R.G., J.E. Gallagher, and M.W. Bianchi. 1976. Water distribution on the Newlands Project, Nevada. Unpublished report, U.S. Department of Interior, Bureau of Reclamation, Lahontan Basin Projects Office, Carson City, NV. 17 pp. + appendix.

Report discusses Bureau operation of project under new OCAP restrictions. Includes results of a simulation modelling effort to predict water supplies to the project under future conditions. Their value of 53.1 in (4.43 ft) for total consumptive use came from a 5-yr study in Idaho with similar conditions to Lahontan Valley.

U.S. Fish and Wildlife Service. 1985-1987. Raw data, unpublished, on file at Stillwater National Wildlife Refuge, U.S. Fish and Wildlife Service, Fallon, NV. 12 pp.

Raw data for various stations in Lahontan Valley that includes electrical conductivity,

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water temperature, and general comments on conditions.

Hoffman, R.J., R.J. Hallock, T.G. Rowe, M.S. Lico, H.L. Burge, and S.P. Thompson. 1990. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in and near Stillwater Wildlife Management Area, Churchill County, Nevada, 1986-87. U.S. Geological Survey, Water-Resources Investigations Report 89-4105, Carson City, NV. 150 pp. + 1 plate.

Purpose of study is to determine whether the quality of irrigation drainage near SWMA has caused harmful effects on human health, fish and wildlife, or may adversely affect the suitability of water for beneficial uses. They sampled surface and ground water, bottom sediment, and biota (plants and animal tissues) from the Carson Desert (upstream and downstream of Fallon agricultural area). In areas affected by irrigation drainage, metals and radioactive substances exceeded baseline levels in water (As, B, dissolved solids, Na, NO3), bottom sediments (As, Li, Hg, Mo, Se), and the biota (As, B, Cr, Cu, Hg, Se, Zn). In some wetlands, Se and Hg appeared biomagnified and As bioaccumulated. Pesticide contamination was insignificant. Adverse biological effects included gradual vegetative changes and species loss, fish die-offs, waterfowl disease epidemics, and persistent migratory bird deaths.

Rowe, T.G., M.S. Lico, R.J. Hallock, A.S. Maest, and R.J. Hoffman. 1991. Physical, chemical, and biological data for detailed study of irrigation drainage in and near Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake, west-central Nevada, 1987-89. U.S. Geological Survey, Open File Report 91-185, Carson City, NV. 199 pp.

Data on trace element concentrations in surface water, ground water, drift and detritus, bottom sediment, pore water, and biota (plants, invertebrates, fish, and waterfowl). Also data on concentrations of major dissolved constituents, nitrogen, phosphorus, organic carbon, radiochemicals, and organochlorine pesticides are reported.

Lico, M.S. 1992. Detailed study of irrigation drainage in and near wildlife management areas, west-central Nevada, 1987-90. Part A: Water quality, sediment composition, and hydrogeochemical processes in Stillwater and Fernley Wildlife Management Areas. U.S. Geological Survey, Water-Resources Investigations Report 92-4024A, Carson City, NV. 65 pp.

This is a detailed study to determine the geochemical and physical processes that control water quality in the Lead Lake area of the SWMA. Ground water quality is poor and the ground water substantially contributes to Lead Lake. Sediments accumulate trace elements from surface water by adsorption onto grains and clays. Stillwater Point Drain, Stillwater Slough, and TJ Drain contribute most of the dissolved solids. The TJ Drain also delivers the largest load of dissolved solids, boron, and sodium to Lead Lake.

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